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INTERIOR BALLISTICS

by

M. E. Serevryakov

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PART THREE - SOLUTION OF PROBLEMS OF INTERNAL BALLISTICS IN COMPLICATED CASES

SECTION ELEVEN - COMPLICATED CASES

CHAPTER 1 - SOLUTION FOR CASE OF COMBINED CHARGES

1. GENERAL INFORMATION.

In practice, use is made in many cases of charges consisting of a mixture of two samples of powders, one being usually thinner and the other thicker; in this connection, the powders may differ in the shape of their grain - being degressive or progressive - and in their nature - having different propellant forces f and rates of burning u_1.

Such composite or combined charges are employed principally in firing from howitzers to obtain different projectile velocities depending upon combat conditions, for the purpose of destroying targets at all ranges under a definite sufficiently large angle of fall.

Furthermore, combined charges are employed on the firing ground in testing artillery and ammunition equipment whenever it is necessary to select a combination of maximum gas pressure p_m and projectile velocity v_D which it is impossible to obtain with a charge composed of a single type of powder. For example, let it be assumed that "regulation" values for p_m and v_D have been obtained with a definite charge of a given type of powder, but that it is necessary to test the barrel or ammunition at a 10-15% higher pressure p_m and at the same velocity v_D, or else that it is necessary at the regulation pressure p_m to obtain a higher pro-

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jectile velocity v_D for the purpose of testing the action of the gun carriage at a higher recoil velocity. In this case, the problem can be solved by the use of a combined charge, by replacing a part of the regulation charge either with a thinner powder while reducing the total weight of the charge or with a thicker powder while increasing the total weight.

As a rule, on the basis of the tactical and technical requirements, there are predetermined a maximum initial velocity v_{Do} for the full charge (designated as No. 0) and a corresponding velocity v_{Dn} for the minimum charge (charge No. n).

The ballistic computation of the barrel for the full charge at predetermined d, q, and v_{Do} is performed in the usual manner, with certain modifications which take into account the burning characteristics of the powder under declining pressures as the charge weights are reduced. The number of velocities and the number of charges are designated on the basis of the firing conditions, depending upon the predetermined angles of fall of the projectile and the values set for the overlapping of ranges. The number n is set at 5-10 and even higher.

The maximum pressure for the full charge (No. 0) p_{mo} is designated in the usual manner on the basis of the quantity C_{ε}; the maximum pressure for the minimum charge p_{mn} is determined from the cocking conditions of the firing device ($p_{mn} > 500$-700 kg/cm^2).

The corresponding loading densities are found to be in the ranges of $\Delta_0 = 0.40$-0.60, $\Delta_n = 0.10$-0.15. After a scale of initial velocities v_{Do}, v_{D1}, v_{D2}, ... v_{Dn} has been arrived at

on the basis of the solution of the problem of exterior ballistics with proper consideration of the overlapping ranges with adjacent charges, internal ballistics must give the magnitudes of the charges necessary to ensure attainment of the predetermined scale of velocities and the weight ratios of the thin and thick powders composing each of these charges, under the condition that the pressures p_{mi} do not exceed the limits imposed upon them.

In order to solve this problem, it is necessary first to give the procedure for solving the problem of pyrodynamics in the case of a combined charge.

This subject is left completely untouched in the treatises and textbooks of foreign authors, but has been elaborated in detail by many of our own authors [1, 2, 4-6].

2. CHARACTERISTICS OF COMBINED CHARGE.

Let a charge ω_{kg} consist of ω'_{kg} of thin powder and ω''_{kg} of thick powder: $\omega = \omega' + \omega''$. The relative weight of each powder will be designated as follows:

$$\frac{\omega'}{\omega} = \alpha', \quad \frac{\omega''}{\omega} = \alpha'';$$

$$\alpha' + \alpha'' = 1, \quad \alpha'' = 1 - \alpha'.$$

Let it be assumed that these powders possess the following characteristics:

Thin	ω'	α'	$2e_1'$	u_1'	$\frac{e_1'}{u_1'} = I_K'$	$\varkappa'$, λ'	f'
Thick	ω''	α''	$2e_1''$	u_1''	$\frac{e_1''}{u_1''} = I_K''$	$\varkappa''$, λ''	f''

The propellant force of the powder in the composite charge is, in the first approximation, computed in accordance with the usual mixing formula:

$$f = \alpha' f' + \alpha'' f''. \qquad (1)$$

In solving the problem in greater detail, it is necessary to take into consideration the magnitude of f for each instant as a function of the composition of the gases formed prior to that instant:

$$f = \alpha' f' \psi' + \alpha'' f'' \psi''. \qquad (1')$$

Since, as a rule, in the case of combined charges, use is made of pyroxylin powders, whose propellant forces f' and f'' are close to each other, formula (1) can be employed with a sufficient degree of precision. During the burning of a mixture of powders under pressure conditions common to both of them, we shall have:

$$de' = u_1' pdt; \quad de'' = u_1'' pdt.$$

Since, under the common pressure conditions $p = f(t)$, the quantity $\int_0^t pdt$ will have one and the same value for both powders,

the integration of these expressions will give the following equations:

$$\frac{e'}{u'_1} = \frac{e''}{u''_1} = \int_0^t pdt.$$

where e' is one-half of the thickness of the layer of thin powder burnt prior to a given instant, and e" is the same for the thick powder.

Since the quantity $I = \int_0^t pdt$ is common to both powders, it is precisely this quantity that is most conveniently taken as the independent variable in solving problems of internal ballistics for a composite charge. This gives a general solution both for the geometric law of burning and for the physical law of burning.

Prior to a certain instant, let there be burned a fraction ψ' of the thin powder and a fraction ψ'' of the thick powder. In weight units, there will burn $\omega'\psi'_{kg}$ of the former type and $\omega''\psi''_{kg}$ of the latter type; the sum of these weights $\omega'\psi' + \omega''\psi''$ will constitute a certain fraction ψ of the total weight of the mixture ω:

$$\psi = \frac{\omega'\psi' + \omega''\psi''}{\omega} = \alpha'\psi' + \alpha''\psi''. \tag{2}$$

The problem involved in determining the characteristics of the combined charge consists in establishing the form coefficients, Γ, and I_K for the mixture on the basis of the known form coefficients, Γ, and I_K for each of the two types of powders of which the mixture

is composed.

Let us introduce into the general expression for ψ:

$$\psi = \varkappa z + \varkappa\lambda z^2$$

the new independent variable $I = \int_0^t pdt$ to replace z. Upon designating:

$$\frac{I}{I_K} = z; \quad \frac{\varkappa}{I_K} = K \quad \text{and} \quad \frac{\lambda}{I_K} = \text{Л},$$

there is obtained:

$$\psi = \frac{\varkappa}{I_K} I + \frac{\varkappa}{I_K} \frac{\lambda}{I_K} I^2 = KI + K\text{Л}I^2. \qquad (3)$$

Application of this formula to each of the components of the charge gives:

$$\psi' = K'I + K'\text{Л}'I^2; \qquad (3')$$

$$\psi'' = K''I + K''\text{Л}''I^2, \qquad (3'')$$

where:

$$K' = \frac{\varkappa'}{I'_K}; \quad \text{Л}' = \frac{\lambda'}{I'_K}; \quad K'' = \frac{\varkappa''}{I''_K}; \quad \text{Л}'' = \frac{\lambda''}{I''_K}.$$

Upon now substituting expressions (3), (3'), and (3") into (2), we have:

$$KI + K\text{Л}I^2 = \alpha'(K'I + K'\text{Л}'I^2) + \alpha''(K''I + K''\text{Л}''I^2)$$

By equating in this identity the coefficients of the same powers of I, we obtain the following expressions for the

characteristics K, $K\text{Л}$, and Л:

$$K = \alpha' K' + \alpha'' K''; \tag{4}$$

$$K\text{Л} = \alpha' K' \text{Л}' + \alpha'' K'' \text{Л}''; \tag{5}$$

$$\text{Л} = \frac{K\text{Л}}{K}.$$

Consequently, the quantities f, ψ, K, and $K\text{Л}$ for the combined charge are obtained from the corresponding characteristics of the individual components in accordance with the ordinary rule of mixtures.

By differentiating equation (2) with respect to I, and keeping in mind that $dI = pdt$, we obtain:

$$\frac{d\psi}{dI} = \alpha' \frac{d\psi'}{dI} + \alpha'' \frac{d\psi''}{dI},$$

but:

$$\frac{d\psi}{dI} = \frac{d\psi}{pdt} = \Gamma.$$

Consequently:

$$\Gamma = \alpha' \Gamma' + \alpha'' \Gamma''. \tag{6}$$

In the coordinate axes ψ-I, the quantity Γ is the tangent of the slope of the ψ-I curve with respect to the I axis. Let us designate it as γ. Then:

$$\tan \gamma = \alpha' \tan \gamma' + \alpha'' \tan \alpha''. \tag{6'}$$

Formula (6) is applicable both to the geometric and to the physical law of burning. In the former case, we shall have:

$$\Gamma' = \frac{\varkappa'}{I'_K} \sigma'; \quad \Gamma'' = \frac{\varkappa''}{I''_K} \sigma''$$

and for the mixture:

$$\Gamma = \frac{\varkappa}{I_K} \sigma = \alpha' \frac{\varkappa'}{I'_K} \sigma' + \alpha'' \frac{\varkappa''}{I''_K} \sigma''. \tag{7}$$

For the start of burning, $\sigma' = \sigma'' = \sigma = 1$. For powders with the same grain shape, $\varkappa' = \varkappa''$. Thus, equation (7) will assume the following form:

$$\frac{\varkappa}{I_K} = \alpha' \frac{\varkappa'}{I'_K} + \alpha'' \frac{\varkappa''}{I''_K} .$$

This equation connects two unknown quantities $\varkappa$ and I_K for the mixture with the corresponding quantities for the components.

One of these - $\varkappa$ - may be assigned arbitrarily: $\varkappa = \varkappa' = \varkappa''$; then, by cancelling out, we obtain a correlation expressing the nominal average impulse of the mixture of two powders in the following form:

$$\frac{1}{I_K} = \frac{\alpha'}{I'_K} + \frac{\alpha''}{I''_K} ,$$

from which:

$$I_K = \frac{I'_K I''_K}{\alpha' I''_K + \alpha'' I'_K}$$

or:

$$I_K = \frac{I'_K}{\alpha' + \alpha'' z'_K} = \frac{I''_K}{\frac{\alpha'}{z'_K} + \alpha''}, \quad (8)$$

where $z'_K = \frac{I'_K}{I''_K} < 1$ is the relative impulse of the thin powder (*).

Since $\alpha' + \alpha'' = 1$, it follows that:

$$I'_K < I_K < I''_K .$$

Equation (8) shows that, in finding the nominal impulse of the mixture I_K by the rule of mixtures, what is added together are not I'_K and I''_K, but the reciprocal quantities $1/I'_K$ and $1/I''_K$.

As has been shown by investigations, the formula:

$$I_K = \alpha' I'_K + \alpha'' I''_K , \quad (9)$$

employed at one time gives values that are too high in comparison with I_K as computed in accordance with formula (8).

In using formula (9) for the computation, the quantity α' is obtained larger, which, in firing, may lead to too high a pressure in comparison with that required.

(*) $z'_K = y_1$ (according to Drozdov), and $z'_K = \beta_1$ (according to Grave).

3. GRAPHICAL REPRESENTATION OF CORRELATION ψ-I.

The progressive burning characteristic Γ depicted in ψ-I coordinates represents a tangent of angle γ formed by the slope of curve ψ-I and the I-axis. For powders whose burning surface area is constant, $\tan\gamma = 1/I_K$ = const.

In the case of combined charges:

$$\psi = \alpha'\psi' + \alpha''\psi'';$$

$$\Gamma = \alpha'\Gamma' + \alpha''\Gamma''$$

or:

$$\tan\gamma = \alpha' \tan\gamma' + \alpha'' \tan\gamma'',$$

where ψ, Γ, and $\tan\gamma$ are expressed as functions of I.

Since:

$$\tan\gamma' = \frac{1}{I_K'}, \quad \tan\gamma'' = \frac{1}{I_K''} \quad \text{and} \quad \tan\gamma = \frac{1}{I_K},$$

we obtain equation (8):

$$\frac{1}{I_K} = \frac{\alpha'}{I_K'} + \frac{\alpha''}{I_K''}, \tag{8}$$

where I_K is subject to graphical determination.

On the basis of the formulas presented above, there is obtained a simple graphical construction of the law of variation of ψ and Γ as functions of I, both during the burning of the mixture and during the completion of the burning of the remaining thicker powder after the burning of the thinner powder is complete.

for simplicity, there is presented in the diagram the solution for powders with a constant burning area, it being assumed that $\alpha' = 0.4$ and $\alpha'' = 0.6$.

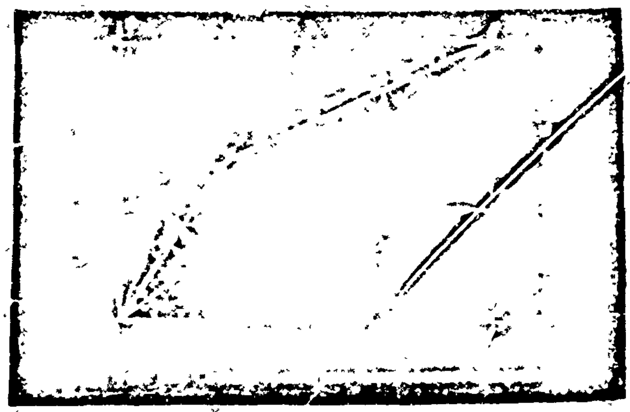

Fig. 168 - Scheme of Burning of Combined Charge.

1) completion of burning of thick powder; 2) mixture.

In fig. 168, the straight line 1 expresses the law of variation ψ'-I for a thin powder with the impulse I_K', while the straight line 2 expresses the law of variation of ψ''-I for a thick powder (I_K'').

In this connection:

$$\tan \gamma' = \frac{1}{I_K'}\ ; \quad \tan \gamma'' = \frac{1}{I_K''}\ ; \quad \tan \gamma = \frac{1}{I_K}\ .$$

To construct the law of variation of ψ for a mixture of powders, the diagram is divided along its height into two parts - a lower part α' (OO') and an upper part α'' (O'O"):

$$\alpha' + \alpha'' = 1.$$

From the point O' at the height α', there is drawn the straight line O'B', which is parallel to the abscissa.

Along the ordinate aA, which corresponds to the impulse I_K', the segment aA' = α'; the straight line OA' gives the values of $\alpha'\psi'$ (the values of the ordinates of the straight line OA multiplied by α'). In the upper part of the diagram, there is drawn from the point O' the straight line O'B; its ordinates, measured from the line O'B', give the values of the second component $\alpha''\psi''$.

In accordance with the formula $\psi = \alpha'\psi' + \alpha''\psi''$, there are added together the corresponding ordinates of the straight lines OA' and O'B; there is obtained the resultant line OC, which expresses the law of variation of ψ as a function of I for the combined charge as long as the two powders burn together.

From the similar triangles OCa and ODd on the one hand and O'CA' and OBB' on the other hand, we obtain:

$$\tan \gamma = \frac{Dd}{Od} = \frac{1}{I_K} = \frac{aC}{Oa},$$

but:

$$\frac{aC}{Oa} = \frac{aA' + A'C}{Oa} = \frac{\alpha'}{I_K'} + \frac{\alpha''}{I_K''},$$

since:

$$\frac{A'C}{Oa} = \frac{A'C}{O'A'} = \frac{B'B}{O'B'} = \frac{\alpha''}{I_K''}.$$

Consequently, we obtain formula (8) by graphical means:

$$\tan\gamma = \frac{1}{I_K} = \frac{\alpha'}{I'_K} + \frac{\alpha''}{I''_K}. \qquad (8)$$

Toward the end of burning of the thin powder (I'_K), there will have burned the following part of the total charge:

$$\psi'_K = aA' + A'C = aA' + BB'\frac{I'_K}{I''_K} = \alpha' + \alpha''\frac{I'_K}{I''_K} =$$

$$= \left(\frac{\alpha'}{I'_K} + \frac{\alpha''}{I''_K}\right) I'_K = \frac{I'_K}{I_K},$$

from which $\psi'_K/I'_K = 1/I_K$; in the diagram, this is represented by the ratio:

$$\frac{aC}{Oa} = \frac{Dd}{I_K} = \frac{1}{I_K}.$$

Consequently, the nominal impulse of the mixture I_K will be obtained by continuing the line OC until it intersects the straight line $\psi = 1$; the corresponding abscissa Od gives the impulse I_K for the mixture.

A break occurs at the point C along the line ψ-I, and thenceforth the law of completion of burning of the thick powder and of the variation of ψ is expressed by the line CB and by the equation:

$$\psi = \alpha' + \alpha''\psi''.$$

GRAPHIC NOT REPRODUCIBLE

Fig. 169 - Variation of Intensive Gas Formation from Combined Charge.

1) Γ of mixture.

Figure 169 shows the construction of the Γ-I diagram for the mixture of the same powders with a constant burning area.

Γ' is characterized by the ordinates of the straight line O'A'; Γ'' is characterized by the straight line O"B"; in this connection $\int_0^{I_K} \Gamma dI = 1$ must be fulfilled as an identity, and since, in the case under consideration, Γ = const, there will prevail for each powder separately $\Gamma' I'_K = 1$ and $\Gamma'' I''_K = 1$.

In conformity with the formula:

$$\Gamma = \alpha'\Gamma' + \alpha''\Gamma'' \quad (6)$$

we first multiply the ordinates Γ'' by α'', obtaining the straight line bb'b" ($\alpha''\Gamma''$); to its ordinates, for the abscissas from zero to I'_K, we add the quantities ba = b'a' ($\alpha'\Gamma'$). The ordinates of the line aa' give the characteristic Γ for the combined charge:

$$\Gamma = \alpha'\Gamma' + \alpha''\Gamma''.$$

In the instant of complete burning of the thin powder with the impulse I_K', the characteristic Γ changes suddenly (from a' to b'), thereupon assuming the form of the straight line b'b" ($\alpha''\Gamma''$), which expresses the intensity of gas formation in the process of completion of burning of the thicker powder with the impulse I_K'' alone.

It is not difficult to show that the shaded area, which expresses the intensity of burning of the combined charge, equals unity, just as in the case of single charges.

As a matter of fact:

(This formula is illegible on the original photostat. Editor.)

since $\Gamma' I_K' = \Gamma'' I_K'' = 1$.

Now, knowing the correlations Γ-I and ψ-I, it is possible to establish the diagram for the correlation Γ-ψ and to apply the resulting data on Γ, ψ, and I for the combined charge to the solution of the problem of internal ballistics.

In solving the problem for the case of the geometric law of burning, it is necessary to know the form characteristics K and Kλ in accordance with formulas (4) and (5) and to apply them in the same manner as in solving the problem for a charge consisting of a single type of powder until the thin powder and the corresponding part of the thick powder have burned.

Following this, the law of gas formation changes, the intensity of gas formation diminishes, and, in solving the problem of pyrodynamics, it becomes necessary to take into account the change in the initial conditions for this phase of burning of

the composite charge.

A detailed theoretical solution of this problem is given in the theoretical part on pyrodynamics.

In the case of the geometric law of burning, the dependence of ψ for the mixture is usually expressed in terms of z'' - the relative thickness of the thicker powder. For powders with the form characteristics of the grain $\varkappa'$, λ' and $\varkappa''$, λ'', we have:

$$\psi' = \varkappa' z' + \varkappa' \lambda' z'^2; \quad \psi'' = \varkappa'' z'' + \varkappa'' \lambda'' z''^2,$$

where:

$$z' = \frac{e'}{e_1'} = \frac{I'}{I_K'}; \quad z'' = \frac{e''}{e_1''} = \frac{I''}{I_K''}.$$

Inasmuch as, for both powders, in a given instant, $I' = I'' = I$ and $I_K' < I_K''$, it follows that $z' > z''$.

Substituting the quantities z' and z'' into the formulas for ψ' and ψ'', we obtain:

$$\psi' = \frac{\varkappa'}{I_K'} I + \frac{\varkappa'}{I_K'} \frac{\lambda'}{I_K'} I^2; \quad \psi'' = \frac{\varkappa''}{I_K''} I + \frac{\varkappa''}{I_K''} \frac{\lambda''}{I_K''} I^2.$$

By expressing the dependence of ψ' in terms of z'', multiplying and dividing by I_K'', and designating $I_K'/I_K'' = z_K'$, we obtain:

$$\psi' = \frac{\varkappa'}{z_K'} \frac{1}{I_K''} + \frac{\varkappa'}{z_K'} \frac{\lambda'}{z_K'} \frac{1}{I_K''} = \frac{\varkappa'}{z_K'} z'' + \frac{\varkappa'}{z_K'} \frac{\lambda'}{z_K'} z'',$$

but:

$$\psi = \alpha'\psi' + \alpha''\psi''.$$

Representation of ψ as a function of z" gives:

$$\psi = \varkappa_{CM} z'' + \varkappa_{CM}\lambda_{CM} z''^2 = \alpha' \frac{\varkappa'}{z'_K} z'' + \alpha' \frac{\varkappa'}{z'_K}\frac{\lambda'}{z'_K} z''^2 + \alpha''\varkappa'' z'' + \alpha''\varkappa''\lambda'' z''^2.$$

We equate the coefficients of the same powers of z":

$$\varkappa_{CM} = \varkappa' \frac{\alpha'}{z'_K} + \alpha''\varkappa''; \quad \varkappa_{CM}\lambda_{CM} = \varkappa'\lambda' \frac{\alpha'}{z'^2_K} + \alpha''\varkappa''\lambda''.$$

Thus, there has been obtained an expression for ψ mixture in the usual form, as a function of z" - the relative thickness of the burnt layer of the thicker powder.

Since the quantity ψ_0 is computed with the aid of the usual formula:

$$\psi_0 = \frac{\frac{1}{\Delta} - \frac{1}{\delta}}{\frac{f_1}{p_0} + \alpha - \frac{1}{\delta}},$$

where $f_1 = \alpha' f' + \alpha'' f''$ is the propellant force of the powder in the combined charge, it follows that:

$$z''_0 = \frac{2\psi_0}{\varkappa_{CM}(1 + \sigma_0)} \approx \frac{\psi_0}{\varkappa_{CM}} = \frac{\psi_0}{\varkappa\left(\frac{\alpha'}{z'_K} + \alpha''\right)},$$

since $G \approx 1$.

Since $z'_K < 1$, it follows that:

$$\frac{\alpha'}{z'_K} + \alpha'' > \alpha' + \alpha'' = 1$$

and z''_0 is smaller than z_0 for a single charge at the same value of ψ_0.

The formulas derived above apply as long as both powders are burning, i.e., until the instant when:

$$z'' = z'_K = \frac{I'_K}{I''_K}; \quad z' = 1 \quad \text{and} \quad \psi' = 1.$$

In that instant:

$$\psi_{K'} = \alpha' + \alpha''\psi''_{K'},$$

where $\psi''_{K'} = \varkappa z'_K + \varkappa\lambda z'^2_{K'}$ is the part of the charge of thick powder which has burned by the time the burning of the thin powder is complete.

4. ANALYTICAL SOLUTION OF PROBLEM

(Written by Professor G. V. Oppokov).

We shall here consider in detail only the simplest case, when the charge consists of powders of two types, both of which are degressive in form and possess the same physico-chemical nature. It is already known that the total interval of burning of the charge must in this case be divided into two phases; by the end of the first phase, all of the thin powder and a part of the thick powder have burned, and the burning of the thick powder is completed in

the course of the second phase.

For the first phase, in the presence of a binomial relation for the law of gas formation, we have:

$$\psi = \varkappa z'' + \varkappa\lambda z''^2.$$

Consequently, the formulas for the single charge retain their significance, as long as the following particulars are observed.

1) The form characteristics $\varkappa$ and $\varkappa\lambda$ are determined with the aid of the following formulas:

$$\varkappa = \frac{\varkappa'}{z'_K}\alpha' + \varkappa''\alpha'' \quad \text{and} \quad \varkappa\lambda = \frac{\varkappa'\lambda'}{z'^2_K}\alpha' + \varkappa''\lambda''\alpha'',$$

where:

$$z'_K = \frac{I'_K}{I''_K}, \quad \alpha' = \frac{\omega'}{\omega}, \quad \alpha'' = \frac{\omega''}{\omega}.$$

2) The quantities z_0 and I_K must be replaced by z''_0 and I''_K for the thick powder, where:

$$z''_0 = \frac{\psi_0}{\varkappa} = \frac{\psi_0}{\varkappa''\left(\frac{\alpha'}{z'_K} + \alpha''\right)}.$$

3) The argument:

$$x = z'' - z''_0; \quad x_{K'} = z''_{K'} - z''_0 = z'_K - z''_0.$$

4) At the end of the first phase, we shall have:

$$z''_{K'} = \frac{e'_1}{e''_1}; \quad x_{K'} = z''_{K'} - z''_0; \quad v'_K = v_{K,0} x_{K'},$$

where:

$$v_{K,0} = \frac{SI''_K}{\varphi m}$$

<u>In the second phase</u>, the differential equation:

$$\frac{dl}{dx} = \frac{Bx(l_\psi + l)}{\psi - \frac{B\theta}{2} x^2} \tag{10}$$

is retained, as is the formula for the velocity of the projectile:

$$v = v_{K,0} x;$$

and the law of gas formation has the following form:

$$\psi = \frac{\omega'}{\omega} + \frac{\omega''}{\omega} \varkappa'' z''(1 + \lambda'' z'').$$

By substituting here the quantity:

$$z'' = z''_0 + x$$

and designating:

$$\psi_{0,2} = \frac{\omega'}{\omega} + \left(\frac{\omega''}{\omega} \varkappa''\right) z''_0 + \left(\frac{\omega''}{\omega} \varkappa'' \lambda''\right) z''^2_0;$$

$$k_{1,2} = \frac{\omega''}{\omega} \varkappa'' + 2 \left(\frac{\omega''}{\omega} \varkappa'' \lambda''\right) z''_0 =$$

$$= \frac{\omega''}{\omega} \varkappa''(1 + 2\lambda'' z_0'') = \frac{\omega''}{\omega} \varkappa'' \sigma_0'',$$

we shall obtain for the second phase:

$$\psi = \psi_{0,2} + k_{1,2}x + \left(\frac{\omega''}{\omega} \varkappa'' \lambda''\right) x^2.$$

Thus, the law of gas formation has a form analogous to the form of the law of gas formation for the first phase:

$$\psi = \psi_0 + k_1 x + \varkappa \lambda x^2.$$

It follows from this that, for the second phase, instead of B and C, use must be made of the quantities B_2 and C_2, where:

$$B_2 = \frac{B\theta}{2} - \left(\frac{\omega''}{\omega} \varkappa'' \lambda''\right); \quad C_2 = \frac{B_2}{k_{1,2}},$$

and then the tabular parameters will be:

$$\beta = C_2 x; \quad \gamma = \frac{C_2 \psi_{0,2}}{k_{1,2}}.$$

Furthermore, in integrating the equation:

$$\frac{dl}{dx} = \frac{Bx(l_\psi + l)}{\psi_{0,2} + k_{1,2}x - B_2 x^2} \qquad (11)$$

it must be taken into consideration that, at the start of the second phase, the path l is equal to the path $l_{K,1}$ of the projectile at the end of the first phase, and the initial value of β equals:

$$\beta_{0,2} = C_2 x_{K,1}.$$

Consequently, approximate integration of equation (11) gives:

$$\ln \frac{l_{\psi_{av.}} + l}{l_{\psi_{av.}} + l_{K,1}} = \int_{x_{K,1}}^{x} \frac{Bxdx}{\psi_{0,2} + k_{1,2}x - B_2x^2} = \frac{B}{B_2} \int_{\beta_{0,2}}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2}, \tag{12}$$

where, as in the first phase:

$$l_{\psi_{av.}} = l_\Delta - a\psi_{av.},$$

but, in contrast with that phase:

$$\psi_{av.} = \frac{\psi_{K,1} + \psi}{2},$$

in which connection $\psi_{K,1}$, the relative fraction of the burnt part of the total charge, is equal at the start of the second phase to:

$$\psi_{K,1} = \varkappa z''_{K,1} + \varkappa\lambda z''^{2}_{K,1} = \psi_0 + k_1 x_{K,1} + \varkappa\lambda x^2_{K,1}.$$

In determining the integral of the right-hand side of equation (11), it is possible to make use of the same table for $\log Z^{-1}$, while keeping in mind, however, that:

$$\log e \int_{\beta_{0,2}}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2} = \log e \int_{0}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2} - \log e \int_{0}^{\beta_{0,2}} \frac{\beta d\beta}{\gamma + \beta - \beta^2} =$$

$$= \log(Z^{-1} Z_{0,2}),$$

Consequently, approximate integration of equation (11) gives:

$$\ln \frac{l_{\psi_{av.}} + l}{l_{\psi_{av.}} + l_{K,1}} = \int_{x_{K,1}}^{x} \frac{Bxdx}{\psi_{0,2} + k_{1,2}x - B_2x^2} = \frac{B}{B_2} \int_{\beta_{0,2}}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2}, \quad (12)$$

where, as in the first phase:

$$l_{\psi_{av.}} = l_{\Delta} - a\psi_{av.},$$

but, in contrast with that phase:

$$\psi_{av.} = \frac{\psi_{K,1} + \psi}{2},$$

in which connection $\psi_{K,1}$, the relative fraction of the burnt part of the total charge, is equal at the start of the second phase to:

$$\psi_{K,1} = \varkappa z''_{K,1} + \varkappa\lambda z''^{2}_{K,1} = \psi_0 + k_1x_{K,1} + \varkappa\lambda x^2_{K,1}.$$

In determining the integral of the right-hand side of equation (11), it is possible to make use of the same table for $\log Z^{-1}$, while keeping in mind, however, that:

$$\log e \int_{\beta_{0,2}}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2} = \log e \int_{0}^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2} - \log e \int_{0}^{\beta_{0,2}} \frac{\beta d\beta}{\gamma + \beta - \beta^2} =$$

$$= \log(Z^{-1}Z_{0,2}),$$

where:

$$\log Z^{-1} = \log e \int_0^{\beta} \frac{\beta d\beta}{\gamma + \beta - \beta^2} \; ; \quad \log Z_{0,2}^{-1} = \log e \int_0^{\beta_{0,2}} \frac{\beta d\beta}{\gamma + \beta - \beta^2}$$

Thus:

$$\ln = \frac{l_{\psi_{av.}} + l}{l_{\psi_{av.}} + l_{K,1}} = \ln (Z^{-B/B_2} Z_{0,2}^{B/B_2}),$$

from which there is finally obtained the desired general relation for the path of the projectile in the second phase:

$$l = (l_{\psi_{av.}} + l_{K,1}) Z_{0,2}^{B/B_2} Z^{-B/B_2} - l_{\psi_{av.}}.$$

Therefore, in comparison with the first phase, the coefficient $l_{\psi_{av.}}$ applied to Z^{-B/B_1} is replaced by the following product:

$$(l_{\psi_{av.}} + l_{K,1}) Z_{0,2}^{B/B_2},$$

where $Z_{0,2}^{B/B_2}$ is a constant quantity for all points in the second phase, which is determined from the table for $\log Z^{-1}$ on the basis of data for γ and $\beta_{0,2}$.

<u>Note:</u> At $\gamma > 0.2$, it is possible to make use of the following formula:

$$\log Z^{-1} = \frac{1}{2} \frac{1}{\sqrt{1 + 4\gamma}} \log \frac{1 + \frac{\beta}{2\gamma}(\sqrt{1 + 4\gamma} + 1)}{1 - \frac{\beta}{2\gamma}(\sqrt{1 + 4\gamma} - 1)}$$

$$- \frac{1}{2} \log \left[1 + \frac{\beta}{\gamma}(1 - \beta) \right].$$

Example 1. To find the principal ballistic elements for the 1909 model, 152-mm field howitzer with a full charge composed of thin Γ_6 powder and thick Γ_6 powder under the following conditions:

$f = 925{,}000$; $\alpha = 0.98$; $\delta = 1.6$; $\theta = 0.18$; $u_1 = 7.1 \cdot 10^{-6}$;
$\omega' = 0.6015$; $0.675 \cdot 14 \cdot 100$ (mm);
$\omega'' = 1.228$; $1.055 \cdot 20 \cdot 100$ (mm);
$s = 1.868$; $W_0 = 4.04$; $l_D = 14.58$;
$q = 40.95$; $\varphi = 1.06 + \frac{1}{3}\frac{\omega}{q}$; $p_0 = 30{,}000$; $g = 98.1$.

Solution. The computations are broken up into separate stages.

I. Preliminary Period.

1) $\varkappa' = 1 + \alpha' + \beta' - \frac{1}{2}\alpha'\beta' = 1.0548$; $\varkappa'\lambda' = -0.0548$;

2) $\varkappa'' = 1 + \alpha'' + \beta'' - \frac{\lambda}{2}\alpha''\beta'' = 1.063$; $\varkappa''\lambda'' = -0.0630$;

3) $\frac{\omega'}{\omega} = \frac{\omega'}{\omega' + \omega''} = 0.3287$;

4) $\frac{\omega''}{\omega} = 0.6713$;

5) $z''_{K,1} = \frac{2e'_1}{2e''_1} = 0.6398$;

6) $\varkappa = \frac{\omega'}{\omega}\frac{\varkappa'}{z'_{K,1}} + \frac{\omega''}{\omega}\varkappa'' = 0.5419 + 0.7136 = 1.2555$;

7) $\varkappa\lambda = \frac{\omega'}{\omega}\frac{\varkappa'\lambda'}{z''^2_{K,1}} + \frac{\omega''}{\omega}\varkappa''\lambda'' = -0.04399 - 0.04229 = -0.08628$;

8) $\frac{1}{\delta_2} = \frac{W_0}{\omega} - \frac{1}{\delta} = 1.583$;.

9) $\frac{1}{\delta_1} = \alpha - \frac{1}{\delta} = 0.355;$

10) $\psi_0 = \frac{1}{\delta_2} : \left(\frac{f}{p_0} + \frac{1}{\delta_1}\right) = 0.0308;$

11) $k_1 = \sqrt{\varkappa^2 + 4\varkappa\lambda\psi_0} = 1.248;$

12) $z''_0 = \frac{2\psi_0}{\varkappa + k_1} = 0.0405;$ $x_{K,1} = z''_{K,1} - z''_0 = 0.5993;$

$x_{K,2} = 1 - z''_0 = 0.9595.$

II. Preliminary Computations for First Phase of First Period.

1) $\varphi = 1.06 + \frac{1}{3}\frac{\omega}{q} = 1.075;$

2) $\frac{\varphi m}{s} = 0.2402;$

3) $I''_K = \frac{e''_1}{u_1} = 742.9;$

4) $v_{K,0} = I''_K : \frac{\varphi m}{s} = 3092;$

5) $\frac{\omega}{s} = 0.9800;$

6) $f\,\frac{\omega}{s} = 906,300;$

7) $l_\Delta = \frac{\omega}{s}\frac{1}{\delta_2} = 1.552;$

8) $a = \frac{\omega}{s}\frac{1}{\delta_1} = 0.3478.$

III. Tabular Constants for First Phase of First Period.

1) $B = I''^2_K : \left(f \frac{\omega}{s} \frac{\varphi m}{s} \right) = 2.534;$

2) $B_1 = \frac{B\theta}{2} - \varkappa\lambda = 0.3144$ (cf. No. 7 in Stage I);

3) $\frac{B}{B_1} = 8.061;$

4) $C = \frac{B_1}{k_1} = 0.2520;$

5) $\gamma = \frac{C\psi_0}{k_1} = 0.01024.$

IV. Ballistic Elements of Shot at End of First Phase of First Period.

1) $\beta_{K,1} = C\,(1 - z''_0) = Cx_{K,1} = 0.1510;$

2) $v_{K,1} = v_{K,0}x_{K,1} = 185.3$ m/sec;

3) $\psi_{K,1} = \psi_0 + k_1x_{K,1} + \varkappa\lambda x^2_{K,1} = 0.7676;$

4) $\psi_{av.} = \frac{\psi_{K,1} + \psi_0}{2} = 0.4092;$

5) $l_{\psi_{av.}} = l_\Delta - a\psi_{av.} = 1.410;$

6) $\log z^{-1}_{K,1} = 0.0577$ (from table of $\log z^{-1}$);

7) $l_{K,1} = l_{\psi_{av.}} z^{-B/B_1}_{K,1} - l_{\psi_{av.}} = 2.704$ dm;

8) $l_{\psi_{K,1}} = l_\Delta - a\psi_{K,1} = 1.285$ dm;

9) $p_{K,1} = f \frac{\omega}{s} \frac{\psi_{K,1} - \frac{B\theta}{2} x^2_{K,1}}{l_{\psi_{K,1}} + l_{K,1}} = 1558 \text{ kg/cm}^2$

V. Ballistic Elements of Shot at p_m.

We anticipate $p_m = 1700$ kg/cm^2. In the first approximation, we find:

$$x_{m,1} = \frac{k_1}{\frac{B(1+\theta)}{1 + \frac{p_m}{f\delta_1}} - 2\varkappa\lambda} = 0.4187.$$

1) $\beta_{m,1} = Cx_{m,1} = 0.1054;$

2) $v_{m,1} = v_{K,0} x_{m,1} = 129.5$ m/sec;

3) $\psi_{m,1} = \psi_0 + k_1 x_{m,1} + \varkappa\lambda x^2_{m,1} = 0.5572;$

4) $\psi_{av.} = \frac{\psi_{m,1} + \psi_0}{2} = 0.3045;$

5) $l_{\psi_{av.}} = l_\Delta - a\psi_{av.} = 1.446;$

6) $\log Z^{-1}_{m,1} = 0.0369;$

7) $l_{m,1} = l_{\psi_{av.}} Z_{m,1}^{-B/B_1} - l_{\psi_{av.}} = 1.423;$

8) $l_{\psi m,1} = l_\Delta - a\psi = 1.358$ dm;

9) $p_{m,1} = f\frac{\omega}{s}\frac{\psi_{m,1} - \frac{B\theta}{2}x^2_{m,1}}{l_{\psi m,1} + l_{m,1}} = 1689$ kg/cm^2

There is no sense in making further approximations, since, generally speaking, there is allowed a ±50 kg/cm^2 discrepancy between the initial and computed p_m. In accordance with literature data, the maximum pressure obtained in firing tests is 1650-1700 kg/cm^2.

VI. Preliminary Computations for Second Phase of First Period.

1) $\psi_{0,2} = \frac{\omega'}{\omega} + \left(\frac{\omega''}{\omega}\varkappa''\right) z_0'' + \left(\frac{\omega''}{\omega}\varkappa''\lambda''\right) z_0''^2 = 0.3576$ (cf. Nos. 6 and 7 in Stage I);

2) $k_{1,2} = \frac{\omega''}{\omega}\varkappa'' + 2\left(\frac{\omega''}{\omega}\varkappa''\lambda''\right) z_0'' = 0.7102.$

VII. Tabular Constants for Second Phase of First Period.

1) $B_2 = \frac{B\theta}{2} - \frac{\omega''}{\omega}\varkappa''\lambda'' = 0.2704;$

2) $\frac{B}{B_2} = 9.374;$

3) $C_2 = \frac{B_2}{k_{1,2}} = 0.3807;$

4) $\gamma = \frac{C_2\psi_{0,2}}{k_{1,2}} = 0.1916;$

5) $\beta_{0,2} = C_2 x_{K,1} = 0.2281;$

6) $\log Z^{-1}_{0,2} = 0.0364$ (knowing γ and $\beta_{0,2}$)

7) $Z_{0,2}^{B_2} = 0.4558.$

VIII. Ballistic Elements at End of Burning of Powder.

1) $\beta_{K,2} = C_2 x_{K,2} = 0.3653;$

2) $v_{K,2} = v_{K,0} x_{K,0} = 296.7$ m/sec;

3) $\psi_{K,2} = \psi_2 + k_{1,2} x_{K,2} + \left(\frac{\omega''}{\omega} \varkappa'' \lambda''\right) x_{K,2}^2 = 1;$

4) $\psi_{av.} = \frac{\psi_{K,2} + \psi_{K,1}}{2} = 0.8838;$

5) $l_{\psi_{av.}} = l_\Delta - a\psi_{av.} = 1.245$ dm;

6) $\log Z_{K,2}^{-1} = 0.0807;$

7) $l_{K,2} = (l_{\psi_{av.}} + l_{K,1}) Z_{0,2}^{B/B_2} Z_{K,2}^{-B/B_2} - l_{\psi_{av.}} = 9.04$ dm;

8) $l_{\psi K,2} = l_\Delta - a\psi_{K,2} = 1.203$ dm;

9) $p_{K,2} = \frac{f\omega}{s} \frac{\psi_{K,2} - \frac{B\theta}{2} x_{K,2}^2}{l_{\psi_{K,2}} + l_{K,2}} = 699$ kg/cm^2.

The resulting values:

$$\psi_{K,2} - \frac{B\theta}{2} x_{K,2}^2 = 1 - \frac{v_K^2}{v_{n_p}^2} = 0.7901;$$

$l_{\psi_{K,2}} = l_1 = 1.203;$ $\log p_{K,2}$ and $-\log(l_1 + l_{K,2})$

will be needed for the next stage.

IX. Ballistic Elements of Shot at Muzzle.

As assigned, $l_D = 14.58$.

1) $v_{np}^2 = \frac{2}{\theta}\left(f\frac{\omega}{s}\right):\left(\frac{\varphi m}{s}\right) = 4.193 \cdot 10^7$;

2) $\eta_D = \frac{l_1 + l_D}{l_1 + l_{K,2}} = 1.539$;

3) $p_D = p_{K,2}\eta_D^{-1-\theta} = 420$ kg/cm^2;

4) $v_D = v_{np}\sqrt{1 - \left(1 - \frac{v_K^2}{v_{np}^2}\right)\eta_D^{-0.2}} = 335.9$ m/sec.

The tabular muzzle velocity is $v_D = 335.3$ m/sec.

5. Use of GAU Tables for the Case of Combined Charges.

The GAU Tables, ANII Tables, and tables of Professor Drozdov are set up for a charge consisting of a single type of powder, which is characterized by the strip-type grain shape ($\varkappa = 1.06$), the strip thickness $2e_1$, and the burning rate u_1 or full impulse $I_K = e_1/u_1$.

The magnitude of the impulse I_K enters into the loading parameter $B = \frac{s^2 I_K^2}{f\omega\varphi m}$, which is a basic quantity in the tables together with the quantity Δ. The relations found above for I_K of the mixture and for the other characteristics make it possible approximately, but with

an accuracy sufficient for practical purposes, to utilize the GAU and other table for the solution of problems in interior ballistics in the case of combined charges.

If the powders composing the charge have the same strip shape, then, knowing I_K' and I_K'', as well as ω, ω', and ω'', the nominal pressure impulse of the mixture of powders I_K is found with the aid of formula (8), substituted into the expression for B, and used in solving the problem in the same manner as in the case of a single powder.

If the powders have different grain shapes, for example degressive (strip or grain of the 4/1 or 7/1 type) and progressive with seven perforations (7/7, 9/7, 12/7, etc.), then, for the degressive powders, $\varkappa = 1.06$ is assumed, and, instead of powders with seven perforations, there is taken the equivalent strip-type powder with the following strip thickness:

$$2e_{1\,\text{strip}} = \frac{10}{7}\,2e_{1\,7\text{ perfor.}}$$

and the impulse $I_K'' = e_1''/u_1''$ is determined for it.

For strip-type as well as for 4/1 and 7/1 powders, the thickness of the powder is not altered, and I_K' is determined in the usual manner: $I_K' = e_1'/u_1'$.

These values for the impulses I_K' and I_K'' are thereupon substituted into formula (8), I_K for the combined charge is found from the known values of α' and α'', and, this quantity having been used to compute the parameter B, the problem is thenceforth solved in the usual manner, as in the case of a single powder.

Thus the solution applicable to a combined charge contains only one additional operation for determining the pulse I_K of the mixture according to formula (8).

The results of computations on the basis of the tables, performed parallel with computations by the analytical methods of Professor Drozdov and Professor Grave, show an almost perfect agreement in the quantities p_m and v_D. But the tabular method with the use of the impulse I_K of the mixture and the parameter B corresponding thereto does not make it possible to determine the actual position of the projectile at the end of burning of the entire charge, which corresponds to the end of burning of the thick powder with the impulse I_K''.

The quantity I_K for the mixture is merely a nominal quantity suitable to characterize the rate of gas formation as long as both powders are burning together (as far as the point C in fig. 168). The actual end of burning can be determined from the velocity curve $v-l$ or $v-\lambda$, if there is marked thereon the ordinate v_K'' corresponding to the end of burning of the thick powder, which is determined for the formula:

$$v_K'' = \frac{sI_K''}{\varphi m}(1 - z_0), \qquad (13)$$

where:

$$z_0 \approx \frac{\psi_0}{\varkappa}, \quad \text{and} \quad \psi_0 = \frac{\frac{1}{\Delta} - \frac{1}{\delta}}{\frac{f}{p_0} + \alpha - \frac{1}{\delta}}$$

From the $v-l$ diagram, on the basis of the quantity v_K'', we can determine the magnitude of the path l_K'', i.e., the position of the

end of burning of the total charge, which is important for establishing the completeness of burning of the powder with a given charge.

In exactly the same manner, with the aid of the formula:

$$v_K'' = \frac{sI_K''}{\varphi m}(1 - z_0),$$

it is possible to determine from the v-l diagram the position of the projectile at the end of burning of the thin powder l_K'.

To determine the percentage content of the thin and thick powders in the mixture for a gun with predetermined design characteristics (W_0, s, Λ_D) at a predetermined Δ, the quantity p_m is used to establish the parameter B from the GAU Tables, Issue No. 1, whereupon there is found the impulse of the mixture:

$$I_K = \frac{1}{s}\sqrt{B l \omega \varphi m}.$$

Knowing the impulses I_K' and I_K'' of the powders composing the mixture and the total weight of the charge $\omega = W_0 \cdot \Delta$, it is possible to find the quantity α' from formula (8), assuming that $\alpha'' = 1 - \alpha'$.

We obtain:

$$\alpha' = \frac{\frac{I_K}{I_K'} - 1}{\frac{I_K''}{I_K} - 1} \qquad (14)$$

and then:

$$\omega' = \omega\alpha'; \quad \omega'' = (1 - \alpha')\omega.$$

In the treatment of results of firing tests from guns, there is usually observed a diminution of the coefficient of utilization of the unit weight of the charge η_ω as the weight of the charge ω/q increases, since, at large ω/q, a larger fraction of the external work is comsumed in moving the gases of the charge and a smaller part remains for the useful work of moving the projectile.

In the treatment of results of firing tests from howitzers with combined charges, there is usually observed a different law of variation of the coefficient η_ω. In some howitzers, in the presence of the minimum charge, $\eta_{\omega n}$ has its minimum value and increases as the weight of the charge increases; in others, as the weight of the charge increases with the increase in the relative weight of the thick powder, the coefficient η_ω at first diminishes, passes through a minimum in the presence of one of the intermediate charges, and then increases again, it usually being the case that, with the full charge, $\eta_{\omega 0}$ is larger than $\eta_{\omega n}$ of the basic minimum charge.

In this connection, as a rule, the velocity v_{Di} varies in accordance with a linear law as a function of the weight of the charge (fig. 170), instead of being convex upward.

GRAPHIC NOT REPRODUCIBLE

Fig. 170 - Variation in v_D and η_ω in Firing with Combined Charge.

1) charge no.

6. PARTICULARS OF BALLISTIC DESIGN OF HOWITZERS AND COMPUTATION OF CHARGES.

The ballistic computation of a howitzer is conducted for the maximum initial velocity v_D, which corresponds to the full charge at the maximum pressure p_{mo}. In this connection, the following data are found: the weight of the full charge No. 0 - ω_0; the fundamental design characteristics of the bore - W_0, Λ_D, $L_{KH} = l_{KH} + l_D$, $W_{KH} = W_0(\Lambda_D + 1)$; and the nominal impulse of the powder mixture for the charge No. 0 - I_{Ko} - which is determined from the parameter B_0. The propellant force of the powder in the charge No. 0 is assumed to be 90-93 tm/kg, unless more accurate data relating to f_0 for a "related" gun are available.

In this connection, contrary to the design of guns firing with one charge and with one initial projectile velocity, for which it is desirable to obtain η_K in the range of 0.60-0.65, η_K for a howitzer with a full charge must be considerably lower (0.25-0.30), in order that the same thick powder be given enough time to burn in the presence of diminished charges and reduced pressures, which

involves the transfer of the end of burning toward the muzzle face.

For this reason, in utilizing the directive diagram, after determining the minimum-volume gun (point M_0) and reducing the weight of the charge (point N), it is necessary to proceed in the direction of reducing Δ and η_K and increasing Λ_D, i.e., to take variants in the lower left sector from the point M_0. In this connection, the characteristic $\eta_D = p_{av.}/p_m$ is obtained smaller than in the case of guns (0.40-0.50).

For the designed gun, using the minimum charge No. n, the predetermined velocity $v_{D,n}$ and the pressure $p_{m,n}$, which is predetermined by the cocking conditions of the firing device, are used to assign Δ_n = 0.10-0.15 and to determine ω_n, B_n, and I'_K - the pressure impulse for the thin powder alone. On the basis of treatment of data for existing howitzers, the propellant force of the powder f' is obtained equal to 80-82 tm/kg.

The computation will in this case follow the course outlines below. Δ_n having been assigned, there are found:

$$\omega_n = W_0 \cdot \Delta_n, \varphi_n = (1.05\text{-}1.06) + \frac{1}{3}\frac{\omega}{q};$$

$$n_f = \sqrt{\frac{\omega}{\varphi q}\frac{f}{95}}; \quad v_{T,D} = \frac{v_{D,n}}{n_f}.$$

At the given Δ_n, from Λ_D and $v_{T,D}$, there are found B_n and:

$$I'_K = \frac{1}{s}\sqrt{B_n f_n \omega_n \varphi_n m};$$

From Δ and B, there are determined the pressure $p_{m\ tab.}$ and:

$$p_{mf} = p_{m\ tab.} \frac{f}{95} .$$

If p_{mf} is smaller than the required p_m, Δ is changed and the computation is repeated until the necessary magnitude is selected for $p_{m,n}$.

The impulse I_K' determined in the final variant will characterize the thin powder composing the basic charge ω_n in the remaining combined charges.

Knowing the weights of the full and minimum charges ω_0 and ω_n, we can find α_0' for the charge No. 0:

$$\alpha_0' = \frac{\omega_n}{\omega_0} ; \quad \alpha_0'' = 1 - \alpha_0' .$$

Knowing I_K for the full charge, which is composed of a mixture of a thin powder with a known impulse I_K' and a thick powder with an unknown impulse I_K'', we determine the latter on the basis of equation (8):

$$\frac{1}{I_{K,o}} = \frac{\alpha_0'}{I_K'} + \frac{\alpha_0''}{I_K''} ,$$

from which:

$$I_K'' = \frac{\alpha_0''}{\frac{1}{I_{K,o}} - \frac{\alpha_0'}{I_K'}} = I_{K,o} \frac{\alpha_0''}{1 - \alpha_0' \frac{I_{K,o}}{I_K'}} .$$

The values of I_K' and I_K'' will subsequently be the same for all intermediate charges.

For the thick powder, f'' is found from the quantities f_0 and f' for the full minimum charges:

$$f_0 = f'\alpha_0' + f''\alpha_0'',$$

from which:

$$f'' = \frac{f_0 - f'\alpha_0'}{\alpha_0''}$$

Usually, f'' is close to 95 tm/kg.

Knowing $v_{D,o}$, $v_{D,n}$, ω_0, ω_n, and the scale of velocities, we designate the weights of the intermediate charges on the basis of the linear relation between v_D and ω:

$$\omega_i = \omega_n + \frac{\omega_0 - \omega_n}{v_{D,o} - v_{D,i}} (v_{D,i} - v_{D,n}).$$

Knowing ω_i, we determine:

$$\Delta_i = W_0\omega_i; \quad \alpha_i' = \frac{\omega_n}{\omega_i}; \quad \alpha_i'' = 1 - \alpha_i';$$

$$f_i = f'\alpha_i' + f''\alpha_i'',$$

The subsequent procedure is as above: $n_{fi} = \sqrt{\frac{\omega_i}{q} \frac{1}{\varphi_i} \frac{f_i}{95}}$ and $v_{tab.D} = v_{D,i}/n_{f,i}$ are computed, and Δ_i, Λ_D, and $v_{tab.D}$ are used to determine B_i, whereupon Δ_i and B_i are used to determine $p_{m\ tab.}$ and $p_{mf} = p_{m\ tab.} \frac{f}{95}$.

CHAPTER 2 - SOLUTION WITH CONSIDERATION OF GRADUAL CUTTING OF ROTATING BAND INTO RIFLING GROOVES OF BARREL

(Professor G. V. Oppokov)

For a consideration of the gradual cutting of the rotating band into the rifling grooves of the barrel, the preliminary period must be divided into two phases: the initial phase and the phase of acceleration of the projectile, at the start of which the pressure of the powder gases attains a magnitude sufficient for the onset of the cutting-in process.

For the initial phase of the preliminary period, it is possible to employ the usual formulas applicable to the preliminary period after replacing therein the quantities:

$$p_0, \psi_0, k_1 \text{ and } z_0$$

by the quantities:

$$p_H, \psi_H, k_H \text{ and } z_H.$$

In the acceleration phase, it will be necessary to deal with an equation of the motion of the projectile of the following type:

$$\varphi m \frac{dv}{dt} = (p - \Pi)s,$$

where Π is the force of resistance of the rotating band to the cutting-in process, related to the unit cross-sectional area s:

$$p = \frac{f\omega\psi - \theta A}{s(l_\psi + l)},$$

it being necessary to represent the total work A of the powder gases in the following form:

$$A = \frac{\varphi m v^2}{2} + A_\Pi.$$

The law governing the force Π and the corresponding work A_Π should be established by experimental means.

Finally, the gas inflow ψ will be found in accordance with the

law of gas formation:

$$\frac{d\psi}{dt} = \frac{p}{I_K}\sqrt{\varkappa^2 + 4\varkappa\lambda\psi},$$

if use is made of the geometric law of burning.

In summary, numerical integration must be applied to a system of equations of the following type:

$$\left.\begin{aligned} \frac{d\psi}{dt} &= \frac{p}{I_K}\sqrt{\varkappa^2 + 4\varkappa\lambda\psi}; \\ \frac{dv}{dt} &= (p - \Pi) : \left(\frac{\varphi m}{s}\right); \\ \frac{dl}{dt} &= v, \end{aligned}\right\} \qquad (15)$$

where:

$$p = f\frac{\omega}{s}\frac{\psi - \frac{B\theta}{2}x^2 - \frac{\theta}{f\omega}A_{\Pi}}{l_{\psi} + l}. \qquad (16)$$

This integration may be carried out in accordance with the variant presented in the books of Professor Oppokov [7-8].

In order to arrive at an analytical method of solution, it is necessary to make three simplifying assumptions for the purpose of determining the velocity of the projectile in the given phase.

1) The variation of ψ in the first equation of the system (15) is neglected:

$$\frac{d\psi}{dt} = \frac{p}{I_K}\sqrt{\varkappa^2 + 4\varkappa\lambda\psi_{\Pi}} = \frac{\varkappa_H}{I_K}p; \qquad (17)$$

2) The small terms in the numerator of the fraction on the right-hand side of formula (16) are neglected, and the following substitution is performed in the denominator:

$$l_{\psi} + l = l_{\Delta} + l_c, \qquad (18)$$

where the average length may be replaced by $\frac{\lambda}{2}$, l being considered to be constant during the integrating operation.

3) A law of the following type is accepted for the force Π:

$$\Pi = \Pi_0 + \Pi_{av.} \frac{l}{l_{Kav.}} = p_H + \Pi_{av.} \frac{l}{l_{Kav.}}, \tag{19}$$

where $l_{Kav.}$ is the path of the projectile at the end of the given phase, the force Π_0 characterizes the "sensitivity of the band", and $\Pi_{av.}$ characterizes its "rigidity".

As a result of the second assumption, we shall have in place of formula (16):

$$p = f \frac{\omega}{s} \frac{\psi}{l_\Delta + l_c},$$

from which, after differentiation, we shall obtain:

$$\frac{dp}{dt} = \frac{f \frac{\omega}{s}}{l_\Delta + l_c} \cdot \frac{d\psi}{dt}$$

or, in accordance with formula (17):

$$\frac{dp}{dt} = \frac{f \frac{\omega}{s}}{l_\Delta + l_c} \cdot \frac{\varkappa_H}{I_K} p.$$

We separate the variables and designate:

$$\tau_{av.} = \frac{I_K}{\varkappa_H} (l_\Delta + l_c) : \left(f \frac{\omega}{s}\right). \tag{20}$$

We find:

$$\frac{dp}{p} = \frac{dt}{\tau_{av.}},$$

from which:

$$p = p_H e^{\frac{t}{\tau_{av.}}}. \tag{21}$$

Through the intermediacy of formulas (19) and (21), the second equation of the system (15) assumes the following form:

$$\frac{d^2 l}{dt^2} = \frac{s}{\varphi m}\left(p_H e^{\frac{t}{\tau_{av.}}} - p_H - \Pi_{av.}\frac{l}{l_{Kav.}}\right), \qquad (22)$$

since:

$$\frac{dv}{dt} = \frac{d^2 l}{dt^2}$$

if the phenomenon of recoil is not taken into account in its explicit form.

By integrating equation (22) in accordance with the known rules of mathematical analysis, and designating for convenience:

$$\tau^2 = \frac{\varphi m}{s} \cdot \frac{l_{Kav.}}{\Pi_{av.}}; \quad k^2 = \frac{\tau^2_{av.}}{\tau^2}; \quad L = \frac{sp_H}{\varphi m}\tau^2_{av.}, \qquad (23)$$

we shall obtain:

$$\left.\begin{aligned} \frac{l}{L} &= \frac{e^{\frac{t}{\tau_{av.}}}}{1+k^2} - \frac{1}{k^2} + \frac{1}{k^2\sqrt{1+k^2}}\cos\left(\tan^{-1}k + k\frac{t}{\tau_{av.}}\right); \\ \frac{\tau_{av.}v}{L} &= \frac{e^{\frac{t}{\tau_{av.}}}}{1+k^2} - \frac{1}{k\sqrt{1+k^2}}\cdot\sin\left(\tan^{-1}k + k\frac{t}{\tau_{av.}}\right), \end{aligned}\right\} \qquad (24)$$

the time t being counted from the start of the given phase.

On the basis of formulas (21) and (24), there have been set up brief tables containing values for the following quantities:

$$\frac{p}{p_H} = e^{\frac{t}{\tau_{av.}}} \text{ (Table 1) and } \frac{\tau_{av.}v}{L} \text{ (Table 2)}$$

as functions of the two parameters $\frac{l}{L}$ and k^2.

These tables are necessary for the solution of the direct problem of interior ballistics with consideration of the gradual cutting of the rotating band of the projectile into the rifling grooves of the barrel.

All formulas for performing computations in connection with the acceleration phase are summarized in Table 3 (p. 926).

The quantities:

$$\varkappa, \quad \frac{1}{\delta_2}, \quad \frac{1}{\delta_1}, \quad \Psi_H, \quad k_H, \text{ and } z_H$$

have already been found in the computations for the initial phase. The quantities p_H and $\Pi_{av.}$ must be known in advance. The argument in this phase is the path l of the projectile. The formula for the pressure in Table 3 has been obtained from formula (16), in which there are taken:

$$A_{\Pi} = 0; \quad \frac{B\theta}{2} x^2 = \frac{v^2}{V_{\Pi p}^2} = \frac{\theta \varphi m}{2 f \omega} v^2.$$

The formula for t in Table 3 is found from expression (21).

The theory of solution of the problem in the first period is analogous to the theory of its solution for a simple charge, except that it is necessary to take into consideration that, at the start of the first period, the projectile has the velocity $v_{Kav.}$ and has already traversed the path $l_{Kav.}$. For this reason, in the first place, integration of the equation for velocity will give:

$$v - v_{Kav.} = \frac{s}{\varphi m}(I - I_{Kav.}),$$

where:

$$I_{Kav.} = \int_0^{t_H + t_{Kav.}} p dt = I_K z_{Kav.}; \quad I = I_K \cdot z.$$

The quantity:

$$v_{K,0} = \frac{s I_K}{\varphi m}$$

may be retained, but for z_0 it is necessary to take:

$$z_0 = z_{Kav.} - \frac{v_{Kav.}}{v_{K,0}} \tag{25}$$

and then, as before:

$$v = v_{K,0}(z - z_0)$$

or:

$$v = v_{K,0}x,$$

where the quantity z_0 is already expressed by formula (25), and the quantity x varies within the limits from:

$$x_{Kav.} = \frac{v_{Kav.}}{v_{K,0}}$$

in the beginning of the first period to the quantity $(1 - z_0)$ at its end.

In the second place, the differential equation for the path of the projectile, in adopting the $l\psi_{av.}$ method and in the presence of the initial conditions:

$$v = v_{Kav.} \text{ and } l = l_{Kav.}$$

gives:

$$l = (l_{\psi av.} + l_{Kav.})Z_{Kav.}^{\frac{B}{B_1}} \cdot Z^{-\frac{B}{B_1}} - l_{\psi av.}.$$

For the formulas needed in the computation of the first period, cf. Table 4, p. 926.

The quantities $v_{Kav.}$ and $Z_{Kav.}$ have already been found with the aid of the formulas in Table 4.

Table 1 - Values of $\frac{p}{p_{II}}$.

$\frac{l}{L}$ \ k^2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.01	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
0.02	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
0.04	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
0.06	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
0.08	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
1.10	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
0.15	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46		
0.20	2.65	2.66	2.66	2.66	2.66	2.67	2.67	2.67			
0.25	2.83	2.84	2.84	2.85	2.85	2.85	2.86				
0.30	3.00	3.01	3.02	3.03	3.03	3.03	3.04				
0.35	3.16	3.17	3.18	3.19	3.19	3.19	3.20				
0.40	3.32	3.33	3.34	3.35	3.35	3.35					
0.45	3.47	3.47	3.49	3.50	3.50	3.50					
0.50	3.60	3.61	3.63	3.64	3.64	3.65					
0.6	3.87	3.88	3.89	3.90	3.90						
0.7	4.12	4.14	4.14	4.15	4.16						
0.8	4.35	4.37	4.38	4.39	4.41						
0.9	4.58	4.60	4.61	4.63	4.65						
1.0	4.80	4.82	4.84	4.87	4.89						
1.1	5.01	5.04	5.06	5.09							
1.2	5.21	5.25	5.28	5.30							
1.3	5.41	5.45	5.49	5.51							
1.4	6.61	6.65	5.69	5.71							
1.5	5.80	5.84	5.88	5.91							
1.6	6.00	6.04	6.08	6.12							
1.7	6.19	6.23	6.27	6.32							
1.8	6.37	6.42	6.46	6.51							
1.9	6.54	6.60	6.65	6.70							
2.0	6.72	6.78	6.83	6.89							
2.2	7.07	7.13	7.19								
2.4	7.41	7.47	7.54								
2.6	7.74	7.81	7.88								
2.8	8.07	8.14	8.23								
3.0	8.39	8.47	8.57								
3.2	8.70	8.79	8.90								
3.4	9.01	9.11	9.23								
3.6	9.32	9.43	9.55								
3.8	9.63	9.75	9.87								
4.0	9.93	10.06	10.19								
4.2	10.23	10.36	10.50								
4.4	10.52	10.65	10.81								
4.6	10.81	10.96	11.12								
4.8	11.10	11.26	11.43								
5.0	11.39	11.56	11.73								
5.2	11.68	11.87									
5.4	11.97	12.17									
5.6	12.35										

Table 2 - Values of $\frac{\tau_{av.} v}{L}$.

$\frac{l}{L}$ \ k^2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	0	0	0	0	0	0	0	0	0	0	0
0.01	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
0.02	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
0.04	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.21
0.06	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
0.08	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
0.10	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.39
0.15	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.54	0.53		
0.20	0.68	0.68	0.67	0.67	0.67	0.66	0.66	0.65			
0.25	0.79	0.79	0.79	0.79	0.78	0.77	0.77				
0.30	0.90	0.90	0.90	0.90	0.89	0.88	0.88				
0.35	1.01	1.01	1.01	1.01	1.00	0.99					
0.40	1.12	1.12	1.12	1.11	1.10	1.08					
0.45	1.22	1.22	1.22	1.21	1.20	0.18					
0.50	1.32	1.32	1.31	1.30	1.29	1.28					
0.6	1.52	1.51	1.50	1.49	1.47						
0.7	1.70	1.69	1.68	1.67	1.65						
0.8	1.87	1.88	1.85	1.84	1.82						
0.9	2.05	2.04	2.02	2.01	2.00						
1.0	2.23	2.21	2.19	2.18	2.17						
1.1	2.40	2.38	2.36	2.34							
1.2	2.57	2.55	2.53	2.50							
1.3	2.73	2.71	2.69	2.67							
1.4	2.89	2.87	2.85	2.83							
1.5	3.05	3.03	3.00	2.98							
1.6	3.21	3.18	3.15	3.12							
1.7	3.37	3.33	3.30	3.27							
1.8	3.52	3.48	3.45	3.42							
1.9	3.66	3.63	3.59	3.56							
2.0	3.81	3.77	3.73	3.70							
2.2	4.11	4.06	4.02								
2.4	4.40	4.35	4.30								
2.6	4.69	4.64	4.58								
2.8	4.98	4.92	4.86								
3.0	5.26	5.20	5.14								
3.2	5.53	5.47	5.41								
3.4	5.81	5.74	5.67								
3.6	6.09	6.01	5.94								
3.8	6.36	6.28	6.21								
4.0	6.63	6.55	6.47								
4.2	6.90	6.81	6.73								
4.4	7.16	7.07	6.99								
4.6	7.42	7.33	7.24								
4.8	7.69	7.59	7.49								
5.0	7.96	7.85	7.74								
5.2	8.22	8.11									
5.4	8.48	8.36									
5.6	8.74										

Table 3 - Formulas for Computing Acceleration Phase.

$$\varphi = K + \frac{1}{3}\frac{\omega}{q}; \quad \frac{\varphi m}{s}; \quad I_K = \frac{e_1}{u_1};$$

$$v_{K,0} = I_K : \frac{\varphi m}{s}; \quad \frac{\omega}{s}; \quad f\frac{\omega}{s};$$

$$l_\Delta = \frac{\omega}{s}\cdot\frac{1}{\delta_2}; \quad l_\alpha = \frac{\omega}{s}\cdot\frac{1}{\delta_1};$$

$$\tau^2 = \frac{\varphi m}{s}\cdot\frac{I_{Kav.}}{\Pi_{av.}}; \quad \tau_1 = \frac{I_K l_\Delta}{f\frac{\omega}{s}k_H}; \quad \frac{\tau_1}{2l_\Delta}; \quad \frac{sp_H}{\varphi m}.$$

$$\tau_{av.} = \tau_1 + \frac{\tau_1}{2l_\Delta}l; \quad k^2 = \frac{\tau^2_{av.}}{\tau^2}; \quad L = \frac{sp_H}{\varphi m}\cdot\tau^2_{av.}$$

$$\psi = \frac{l_\Delta + l + \frac{\theta}{2}\cdot\frac{\varphi m}{s}\cdot\frac{v^2}{p}}{f\frac{\omega}{s}\cdot\frac{1}{p} + l_\alpha};$$

$$z = \frac{2\psi}{\varkappa + k_{av.}}; \quad t = 2.303\tau_{av.}\log\frac{p}{p_H}.$$

Table 4 - Formulas for Computing First Period.

$$x_{Kav.} = \frac{v_{Kav.}}{v_{K,0}}; \quad z_0 = z_{Kav.} - x_{Kav.};$$

$$\psi_0 = \varkappa z_0 + \varkappa\lambda z_0^2; \quad k_1 = \sqrt{\varkappa^2 + 4\varkappa\lambda\psi_0}.$$

$$B = I_K^2 : \left(f\frac{\omega}{s}\cdot\frac{\varphi m}{s}\right); \quad B_1 = \frac{B\theta}{2} - \varkappa\lambda;$$

$$\frac{B}{B_1}; \quad C = \frac{B_1}{k_1}; \quad \gamma = \frac{C\psi_0}{k_1};$$

$$\beta_{Kav.} = Cx_{Kav.}; \quad \log z^{-1}_{Kav.}; \quad z_{Kav.}^{\frac{B}{B_1}}.$$

$$\beta = Cx; \quad v = v_{K,0}x; \quad \psi = \psi_0 + k_1x + \varkappa\lambda x^2;$$

$$\psi_{av.} = \frac{\psi + \psi_{Kav.}}{2}; \quad l_c = l_\Delta - l_\alpha\psi_{av.}; \quad l = (l_c + l_{Kav.})z_{Kav.}^{\frac{B}{B_1}}z^{-\frac{B}{B_1}} - l_c.$$

$$l_\psi = l_\Delta - l_\alpha\psi; \quad p = f\frac{\omega}{s}\frac{\psi - \frac{B\theta}{2}x^2}{l_\psi + l}.$$

Example 1. To find the ballistic elements of a shot at the end of the preliminary period with consideration of the gradual cutting of the rotating band of the projectile into the rifling grooves of the barrel for the 1942 model 76 mm light division gun (ZIS-3) under the following loading conditions:

$$f = 896,000; \quad \alpha = 1; \quad \delta = 1.6; \quad \theta = 0.2;$$

$$\omega = 1.08; \quad 2e_1 = 1.4 \text{ mm}; \quad \varkappa = 1.06;$$

$$W_0 = 1.49; \quad s = 0.4692; \quad l_D = 26.88; \quad l_{Kav.} = 0.33;$$

$$q = 6.2; \quad \varphi = 1; \quad p_H = 15,000; \quad \Pi_{av.} = 10,000.$$

I. Initial Phase of Preliminary Period.

1) $\varkappa = 1.06$ (given); 2) $\frac{1}{\delta_2} = \frac{W_0}{\omega} - \frac{1}{\delta} = 0.755$; 3) $\frac{1}{\delta_1} = \alpha - \frac{1}{\delta} = 0.375$;

4) $\psi_H = \frac{1}{\delta_2} : \left(\frac{f}{p_0} + \frac{1}{\delta_1}\right)$; $\log \psi_H = \overline{2}.0987$; 5) $\varkappa_H = \sqrt{\varkappa^2 + 4\varkappa\lambda\psi_H}$; $\log k_H = 0.0248$.

II. Preliminary Computations for Acceleration Phase.

1) $\varphi = K + \frac{1}{3}\frac{\omega}{q} = 1$ (given); 2) $\log \frac{\varphi m}{s} = \overline{1}.1293$; 3) $I_K = 938.5$; $2e_1 = 1.4$;

4) $\log v_{K,0} = \log\left(I_K : \frac{\varphi m}{s}\right) = 3.8431$; 5) $\log \frac{\omega}{s} = 0.3620$; 6) $\log f\frac{\omega}{s} = 6.3143$

7) $\log l_\Delta = \log \frac{\omega}{s} \cdot \frac{1}{\delta_2} = 0.2399$; 8) $\log l_\alpha = \log \frac{\omega}{s} \cdot \frac{1}{\delta_1} = \overline{1}.9360$;

9) $\log \tau^2 = \log\left(\frac{\varphi m}{s} \cdot \frac{l_{Kav.}}{\Pi_{av.}}\right) = 6.6478$; 10) $\log \tau_1 = \log \frac{I_K l_\Delta}{f\frac{\omega}{s} k_H} = 4.8732$;

11) $\log \frac{\tau_1}{2l_\Delta} = \overline{4}.3323$; 12) $\log\left(p_H : \frac{\varphi m}{s}\right) = 5.0468$.

III. Ballistic Elements at End of Preliminary Period.

Knowing from the assignment that $l = l_{Kav.} = 0.33$ dm, we obtain from the formulas in the middle section of Table 3:

1) $\tau_{av.} = \tau_1 + \frac{\tau_1}{2l_\Delta} l_{Kav.} = 0.709\cdot 10^{-4}$; 2) $k^2 = \frac{\tau^2_{av.}}{\tau^2} = 0.150$;

3) $L = \tau^2_{av.}\left(p_H : \frac{\varphi m}{s}\right)$; $\log L = \bar{2}.8720$; 4) $\frac{l}{L} = \frac{l_{Kav.}}{L} = 4.43$.

Knowing that $\frac{l}{L} = 4.43$ and $k^2 = 0.150$, we use Tables 1 and 2 to obtain by double interpolation:

5) $\frac{p_{Kav.}}{p_H} = 10.78$ and 6) $\frac{\tau_{av.} v_{Kav.}}{L} = 7.07$, which makes it possible to find for the end of the preliminary period:

7) $p_{Kav.} = 10.82 p_H = 1617$ kg/cm²; 8) $v_{Kav.} = \frac{7.13L}{\tau_{av.}} = 64.3$ m/sec.

We continue the computations in accordance with the formulas in the lower section of Table 3:

$$8)\ \psi_{Kav.} = \frac{l_\Delta + l_{Kav.} + \frac{\theta}{2}\frac{\varphi m}{s}\cdot\frac{v^2_{Kav.}}{p_{Kav.}}}{f\frac{\omega}{s}\cdot\frac{1}{p_{Kav.}} + l_\alpha};\quad \log\psi_{Kav.} = \bar{1}.1887;$$

$$9)\ k_{av.} = \sqrt{\varkappa^2 + 4\varkappa\lambda\psi_{Kav.}} = 0.0181;\quad 10)\ z_{Kav.} = \frac{2\psi_{Kav.}}{\varkappa + k_{av.}} = 0.1469;$$

$$11)\ t_{Kav.} = 2.303\tau_{av.}\log\frac{p_{Kav.}}{p_H} = 0.001944 \text{ sec}.$$

Without consideration of the gradual cutting-in process, there were at the end of the period:

$$l = 0;\quad v_0 = 0;\quad p_0 = 300 \text{ kg/cm}^2$$

With consideration of the cutting-in process, these changed to:

$$l_{Kav.} = 0.33;\quad v_{Kav.} = 64.3 \text{ m/sec};\quad p_{Kav.} = 1617 \text{ kg/cm}^2$$

Example 2. To find the principal ballistic elements of the shot under the conditions of Example 1 and from its results.

Solution. We perform the computations with the aid of the formulas in Table 4.

IV. Preliminary Computations for First Period.

$$1)\ x_{Kav.} = \frac{v_{Kav.}}{v_{K,0}} = 0.0924;\quad 2)\ z_0 = z_{Kav.} - x_{Kav.} = 0.0545;$$

$$3)\ \psi_0 = \varkappa z_0 + \varkappa\lambda z_0^2 = 0.0756;\ 4)\ k_1 = \sqrt{\varkappa^2 + 4\varkappa\lambda\psi_0} = 1.0226.$$

V. Tabular Constants for First Period.

$$1)\ B = I_K^2 : \left(f\,\frac{\omega}{s}\cdot\frac{\varphi m}{s}\right) = 3.171;\quad 2)\ B_1 = \frac{B\theta}{2} - \varkappa\lambda = 0.3771;$$

$$3)\ \log\frac{B}{B_1} = 0.9248;\ 4)\ \log C = \log\frac{B}{k_1} = \bar{1}.5538;\ 5)\ \gamma = \frac{C\psi_0}{k_1} = 0.0196;$$

6) $\beta_{Kav.} = Cx_{Kav.} = 0.0331$; 7) $\log Z^{-1}_{Kav.} = 0.0060$ (form table $\log Z^{-1}$, knowing γ and $\beta_{Kav.}$); 8) $\log Z_{Kav.}^{\frac{B}{B_1}} = \bar{1}.9495$.

For the stages VI and VII, we employ the formulas in the lower section of Table 4 ($\log x_{m,1} = \bar{1}.4676$; $\log x_K = \bar{1}.9756$):

$v_K = 658.8$ m/sec; $\psi_K = 1$; $l_K = 22.53$ dm; $p_K = 606$ kg/cm^2; $v_{m,1} = 204.5$; $\psi_{m,1} = 0.3615$; $l_{m,1} = 1.502$; $p_{m,1} = 2345$.

For the stage VIII, we employ the formulas of Section 4, Chapter 1, Part Two:

$$\log \eta_D = 0.0555;$$

$$p_D = 519\ \text{kg/cm}^2;\quad v_D = 679.5\ \text{m/sec}.$$

It is already known that, by experiment:

$$p_m = 2320\ \text{kg/cm}^2\ \text{and}\ v_D = 680\ \text{m/sec}.$$

CHAPTER 3 - SOLUTION OF PROBLEM OF INTERNAL BALLISTICS FOR MORTARS

1. General Information.

In comparison with a shot from an ordinary artillery gun, a shot from a mortar has a number of specific features. For this reason, the burning of the powder and the other processes connected with the work of the powder gases during a shot from a mortar proceed under conditions which are more complex and less known in some respects, but simpler in other respects.

The basic charge of a mortar (fig. 171) is contained in a cardboard cartridge (shell case) inserted in the stabilizer tube 1 (tail of the mortar shell). The tube has four or six rows of circular openings 2, through which the powder gases formed within the shell case must flow out into the space behind the mortar shell once the cardboard has been pierced.

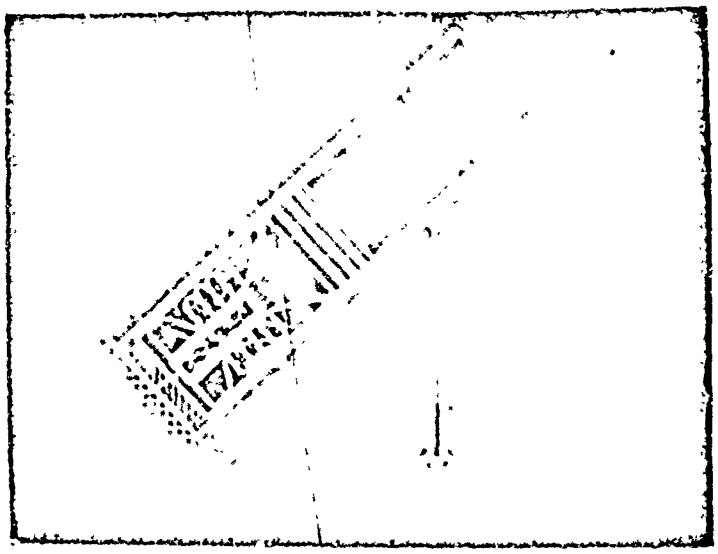

Fig. 171 - Sketch of Arrangement of Mortar.

During loading, the mortar shell is lowered to the bottom of

the bore, displacing the air through the clearance 3. The percussion cap of the cartridge with the basic charge strikes the firing pin 4, which is fixed in the bottom of the bore of the mortar, and ignition of the percussion cap and powder charge takes place; in this connection, the powder burns first in the closed space of the cartridge at a rather high loading density Δ_0 = 0.50-0.60. In a certain instant, the gas pressure pierces the walls of the cardboard cartridge, and the gases of the basic charge flow through the openings 2 in the stabilizer tube into the chamber space W_0.

Under these conditions of very rapid burning of a very thin fine powder, the maximum gas pressure inside the stabilizer tube is, as has been shown by experiments, very sensitive both with respect to the size of the tube openings and the thickness of the cartridge walls, and with respect to the most insignificant delays or advances in the piercing of the cartridge walls.

As a result of a small difference in the pressures under which the cartridge walls are pierced, there may ensue a large scattering of the magnitudes of maximum pressure in the stabilizer tube.

For this reason, it is precisely in a mortar, in greater measure than in a gun, that importance attaches to the composition, the weight of the igniting percussion cap, and the rate of burning of the powder; the greater the impulse provided by the igniter the more uniformly is the powder ignited.

The next characteristic feature consists in the fact that the gases of the basic charge, which first burns inside the stabilizer chamber at Δ = 0.50-0.60, undergo strong expansion and cooling as they flow out into the space behind the mortar shell. Since the surface of the stabilizer vanes 2 and of the bottom part of the mortar

shell is large, while the loading density of the basic charge with respect to the total chamber volume W_0 is small (Δ = about 0.01), there occurs a large loss of heat to the walls of the bore and of the mortar shell, this loss being still more accentuated by the slow motion of the mortar shell and by the long interval of time during which the gases remain in contact with the walls of the mortar.

If additional charges ω are present, the powder contained therein is ignited by the action of the gases of the basic charge, and the motion of the mortar shell proceeds under the action of the total gas pressure produced by the basic and additional charges. Owing to the presence of the clearance 3 between the mortar shell and the walls of the bore, a portion of the gases will penetrate through this clearance from the very outset of the motion of the mortar shell, and consequently their energy will not be utilized.

In gas-regulator mortars, with the gas regulator open, a considerable part of the gases also escapes through the gas regulator. The existence of a penetration of gases through the clearance between the mortar shell and the bore and through the gas regulator constitutes the third characteristic feature of the shot from a mortar. The consumption of gases through the clearance and the gas regulator is accounted for on the basis of the general relations of gas dynamics.

As shown by slow-motion photographs, a considerable part of the gases is ejected from the bore of the mortar prior to the emergence of the mortar shell from the barrel, which is accompanied by the ejection of the principal mass of the gases. This part of the gases which is ejected through the clearance and does not participate in

communicating a velocity to the mortar shell constitutes as much as 10-15% of the total quantity of gases, whereas, in an ordinary gun, the fraction of gases ejected through the clearances between the rotating band and the grooves of the rifling is insignificant.

The fourth characteristic feature consists in the fact that the pressure to overcome the inertia of the projectile may in practice be considered as being equal to zero. In exactly the same manner, no energy has to be expended in a smooth barrel to overcome friction and to rotate the mortar shell.

Thus, the solution of the problem of internal ballistics is, on the one hand, simplified by the fact that the pressure to overcome the inertia of the projectile and a portion of the secondary work are assumed to be zero; on the other hand, the solution of the problem is complicated by the necessity of taking into account a greater heat loss and the escape of gases through the clearance and gas regulator, which requires the utilization of the fundamental relations of gas dynamics.

Since, in a shot from an ordinary mortar resting on a base plate, there occurs practically no recoil, and the relative weight of the charge ω/q is very small (of the order of 0.01-0.02 with a full charge), it is possible to assume in practice that the coefficient $\varphi = 1$.

To retain unity in the procedure and in the designations of the parameters and functions, the solution of the fundamental problem of internal ballistics for mortars, which is developed below, is presented in the designations of Professor Drozdov for ordinary artillery guns.

2. ANALYTICAL SOLUTION OF FUNDAMENTAL PROBLEM FOR SMOOTH-BORE MORTARS.

(Simplified Method of Professor M.E. Serebryakov)

The analytical solution is based on the following assumptions:

1) There is no pressure to overcome the inertia of the projectile. The mortar has an annular clearance between the mortar shell and the bore.

2) The burning of the basic charge in the stabilizer tube is not considered.

The gases of the basic charge flowing from the stabilizer tube into the space behind the mortar shell produce in that space the pressure p_0, under which the powder of the additional charges is ignited. Thus, the basic charge acts as an igniter for the additional charges.

3) The ignition of the additional charges is assumed to be instantaneous and simultaneous for all grains and for all points on the surface of every grain.

4) The burning of the grains of the additional charges proceeds in parallel layers in conformity with the geometric law of burning and is expressed by the following known formulas:

$$\psi = \varkappa z + \varkappa \lambda z^2;$$

$$\sigma = 1 + 2\lambda z.$$

5) The rate of burning of the powder is proportional to the pressure (in the first power):

$$u = \frac{de}{dt} = u_1 p,$$

where u_1 is the rate of burning at $p = 1$.

6) The motion of the mortar shell begins under the pressure p_0 simultaneously with the start of burning of the additional charges (at $p = p_0$, $\psi_0 = 0$, $l = 0$, $v = 0$).

7) The escape of gases through the clearance begins simultaneously with the start of burning of the additional charges and with the beginning of motion of the mortar shell.

8) The complete impulse of the increase in pressure $\int_0^{t_K} pdt = \frac{e_1}{u_1}$ is independent of the loading density Δ and of the magnitude of the initial pressure p_0 under which the powder is ignited.

9) On the basis of the general formulas of gas dynamics, the escape of gases through the clearance is proportional to the impulse of the increase in pressure:

$$Y = \omega\eta = \zeta' A s_{clearance} \int_0^t pdt = \zeta' A s_{clearance} I,$$

where η is the part of the gases which has escaped through the clearance; A is the coefficient of escape:

$$A = \left(\frac{2}{k+1}\right)^{\frac{1}{k-1}} \sqrt{\frac{2gk}{k+1} \cdot \frac{1}{f}};$$

ζ' is a coefficient which characterizes the form and arrangement of the clearance; and $s_{clearance}$ or s_3 is the cross-sectional area of the clearance.

10) The heat loss is determined on the basis of experiments in a special apparatus, in which the basic charge burns under the same conditions as in the mortar.

By experimentally determining in this apparatus the maximum gas pressure of the gases of the basic charge in a constant volume $p_{m,0}$,

there is found the propellant force of the powder f_0 in the basic charge with consideration of the cooling of the gases by their expansion from the stabilizer tube into the space behind the mortar shell and by the heating of the walls of the bore and of the stabilizer vanes:

$$f_0 = p_{m,\ 0}\left(\frac{1}{\Delta_0} - \alpha_0\right),$$

where Δ_0 is the loading density of the basic charge with respect to the entire volume behind the mortar shell W_0 (chamber). This quantity f_0 is obtained considerably smaller than the propellant force f of the powder in the additional charges composed of powder of the same nature, which is determined on the basis of experiments in an ordinary manometric bomb.

The subsequent heat transfer during the motion of the mortar shell is neglected (since the walls of the bore and of the mortar shell are heated by the gases escaping through the annular clearance in advance of the mortar shell), or else is taken into account indirectly. Since no work is performed by the gases to rotate the mortar shell, to overcome friction along the grooves of the rifling, and to bring about a recoil, and since $\omega/q = 1\%$, the coefficient of consideration of secondary work φ may be assumed to be equal to unity.

The phenomenon of the shot is subdivided into the following periods:

1) Burning of the basic charge until openings are pierced in the cartridge and the gases flow out into the chamber; on the basis of the assumptions made above, this phase is analogous to the preliminary period.

2) The first per ›d corresponds to the burning of the additional charges, accompanied by the simultaneous escape of a part of the gases through the clearance (l varies from zero to l_K).

3) The second period corresponds to the expansion of the gases already formed in the first period, accompanied by their simultaneous escape through the clearance $s_{clearance}$.

The motion of the mortar shell and the escape of the gases through the clearance (based on the assumptions made) begin under the pressure p_0, produced by the gases of the basic charge, which can be determined in the test apparatus:

$$p_0 = \frac{f_0\omega_0}{W_0 - \frac{\omega}{\delta} - \alpha\omega_0} = \frac{f\Delta_0}{1 - \frac{\Delta}{\delta} - \alpha_0\Delta_0},$$

where:

$$\Delta = \frac{\omega}{W_0};$$

$$\Delta_0 = \frac{\omega_0}{W_0}.$$

Let s be the cross-sectional area of the bore of the mortar, $s = \frac{\pi}{4} d^2$; s' the cross-sectional area of the mortar shell at its centering land; and $s_{clearance} = s - s'$, the area of the clearance between the mortar shell and the walls of the bore.

The velocity of the projectle is determined from the following equation of motion:

$$\varphi m dv = s' p dt;$$

$$v = \frac{s'}{\varphi m} \int_0^t p dt = \frac{s'}{\varphi m} I = \frac{s' I_K}{\varphi m} z,$$

where:

$$z = \frac{I}{I_K} = \frac{e}{e_1}.$$

For the solution of the problem, we have the following system of equations:

1) The fundamental equation of pyrodynamics with consideration of the escape of a part of the gases through the clearance and of heat losses:

$$sp(l'_\psi + l) = f_0\omega_0 + f\omega\psi - f'Y - \frac{\theta}{2}\varphi m v^2.$$

The quantity f' is the force of the mixture of gases of the basic and additional charges; essentially, it varies during the burning of the additional charge from f_0 to $\frac{f_0\omega_0 + f\omega}{\omega_0 + \omega} < f$, having in the intermediate instants the value:

$$f' = \frac{f_0\omega_0 + f\omega\psi}{\omega_0 + \omega\psi}.$$

Since, for the present, the heat transferred to the walls is not considered directly (cf. Assumption 10), it can be taken into account indirectly by taking instead of the value f' a value for f of the additional charges that is larger than f'. In this case, the fundamental equation will be rewritten in the following manner:

$$sp(l'_\psi + l) = f_0\omega_0 + f(\omega\psi - Y) - \frac{\theta}{2}\varphi mv^2, \tag{26}$$

where:

$$l'_\psi = \frac{1}{\delta}\left[W_0 - \frac{\omega}{\delta}(1-\psi) - \alpha(\omega\psi - Y) - \alpha_0\omega_0\right]$$

takes into account the loss of gases through the clearance s - s'.

2) The equation of motion of the mortar shell:

$$s'pdl = \varphi mvdv. \tag{27}$$

$$\psi = \varkappa z + \varkappa\lambda z^2 \tag{28}$$

3) The (geometric) law of burning for lamellar fine powders and $\psi = z$ for flat disk-shaped powders.

4) The formula for the velocity of the mortar shell:

$$v = \frac{s'I_K}{\varphi m} z. \tag{29}$$

5) The relative consumption of gases:

$$\eta = \frac{Y}{\omega} = \frac{\zeta' A s_3 I_K}{\omega} z = \eta_K z, \tag{30}$$

where:

$$\eta_K = \frac{\zeta' A s_3 I_K}{\omega} = \frac{\zeta' A s_3}{\omega}\frac{e_1}{u_1}. \tag{31}$$

$\zeta' < 1$ is a coefficient which takes into account the shape of the opening through which the gases flow out; and η_K is the relative consumption of gases at the end of burning of the powder.

The following designations are introduced:

$$B' = \frac{s'^2 I_K^2}{f\omega\varphi m} = \left(\frac{s'}{s}\right)^2 \frac{s^2 I_K^2}{f\omega\varphi m} = \left(\frac{s'}{s}\right)^2 B;$$

$\chi_0 = \frac{f_0\omega_0}{f\omega}$ is the relative energy of the basic charge.

By replacing in equation (26) the quantities ψ, v, and Y (or η) by their expressions (28), (29) and (30) in terms of z, we obtain the fundamental equation of pyrodynamics in the following form:

$$sp(l'_\psi + l) = f\omega\left[\chi_0 + \varkappa z + \varkappa\lambda z^2 - \eta_K z - \frac{B'\theta}{2} z^2\right] = f\omega\left[\chi_0 + (\varkappa - \eta_K) z - \left(\frac{B'\theta}{2} - \varkappa\lambda\right) z^2\right]. \tag{32}$$

From equation (27), we have:

$$s'p\, dl = \frac{s'^2 I_K^2}{\varphi m} z\, dz. \tag{33}$$

Upon dividing (33) by (32) term by term, we obtain:

$$\frac{s'}{s} \frac{dl}{l'_\psi + l} = B' \frac{zdz}{\chi_0 + k_1' z - B_1' z^2} = -\frac{B'}{B_1'} \frac{zdz}{z^2 - \frac{k_1'}{B_1'} z - \frac{\chi_0}{B_1'}} = -\frac{B'}{B_1'} d \ln Z,$$

where:

$$k_1' = \varkappa - \eta_K; \quad B_1' = \frac{B'\theta}{2} - \varkappa\lambda; \quad A_s = \frac{s}{s'} \frac{B'}{B_1'}.$$

Z is a known function developed by Professor N.F. Drozdov. We

thus obtain:

$$\frac{dl}{l'_{\psi} + l} = -A_s \frac{z dz}{\xi_1(z)} = -A_s d \ln Z. \qquad (34)$$

Equation (34) can be solved exactly by the method of Professor N.F. Drozdov, which involves its reduction to the form of a first-order linear differential equation; but, taking into account that the loading densities in mortars are small ($\Delta < 0.15$), and consequently l'_{ψ} varies very little, it is possible to assume l'_{ψ} to be equal to the mean value of $l'_{\psi} = l'_{\psi av.}$. After integration, we obtain a simple expression for the path of the mortar shell in the following form:

$$\frac{l'_{\psi av.} + l}{l'_{\psi av.}} = 1 + \frac{l}{l'_{\psi av.}} = Z^{-A_s},$$

from which:

$$l = l'_{\psi av.}(Z^{-A_s} - 1).$$

The value of $\log Z^{-1}$ is determined from the table of Professor N.F. Drozdov in conformity with the basic quantities:

$$\gamma = \frac{B'_1 \chi_0}{k_1'^2}, \qquad \beta = \frac{B'_1}{k'_1} z.$$

Consequently, the solution of the problem for the first period in the mortar differs from the solution for the artillery gun only by the fact that, in conjunction with z, the coefficient $k_1 = \varkappa \sigma_0$ has been replaced by the coefficient $k'_1 = \varkappa - \eta_K$, the quantity $\chi_0 = \frac{f_0 \omega_0}{f \omega}$ has appeared in the place of ψ_0, and the quantity B' =

$= B\left(\frac{s'}{s}\right)^2$ has appeared in the place of B. All this, reflecting the characteristic features of the shot from mortars, is manifested in the quantities $\gamma = \frac{B_1'\chi_0}{k_1'^2}$ and $\beta = \frac{B_1'}{k_1'}z$, which, in turn, increases the values of $\overline{Z}^{-1}$ and of the path l, and reduces the magnitude of the pressure p in comparison with the pressure under conditions involving the absence of gas escape.

The pressure p is found from the following formula, which is derived from equation (26):

$$p = \frac{f\omega}{s}\,\frac{\chi_0 + \psi - \eta - \frac{\theta}{2}\frac{\varphi m v^2}{f\omega}}{l_\psi' + l} = \frac{f\omega}{s}\,\frac{\chi_0 + k_1'z - B_1'z^2}{l_\psi' + l}. \qquad (35)$$

To determine z_m, which corresponds to the maximum gas pressure p_m, we differentiate the expression (35) with respect to z, and, using equation (34), obtain after a series of transformations:

$$z_m = \frac{\varkappa\left(1 + \frac{p_m}{f\delta_1}\right) - \eta_K\left(1 + \frac{\alpha p_m}{f}\right)}{B'\left(\frac{s}{s'} + \theta\right) - 2\varkappa\lambda\left(1 + \frac{p_m}{f\delta_1}\right)} = \frac{\varkappa - \eta_K\left(\frac{1 + \frac{\alpha p_m}{f}}{1 + \frac{p_m}{f\delta_1}}\right)}{\frac{B'\left(\frac{s}{s'} + \theta\right)}{1 + \frac{p_m}{f\delta_1}} - 2\varkappa\lambda}, \qquad (36)$$

where $\frac{1}{\delta_1} = \alpha - \frac{1}{\delta}$.

At $\eta_K = 0$ and $s = s'$, this formula is transformed into the usual formula for z_m.

If $z_m \leqslant 1$, we have a real pressure maximum; if $z_m > 1$, the maximum is unreal, and in this case the highest actual pressure will be the pressure at the end of burning p_K:

$$p_K = \frac{f\omega}{s} \frac{1 + \chi_0 - \eta_K - \frac{B'\theta}{2}}{l_1' + l_K},$$

where:

$$l_1' = l_0 \left[1 - \alpha\Delta(1 - \eta_K)\right] \quad \text{and} \quad \Delta_K = \frac{\omega}{W_0}(1 - \eta_K) = \Delta(1 - \eta_K).$$

The remaining elements at the end of the first period will be:

$$v_K = \frac{s'I_K}{\varphi m}; \quad l_K = l'_{\psi av.}(Z_K^{-A_s} - 1),$$

in which connection:

$$\beta_K = \frac{B_1'}{k_1'}.$$

For solving the problem <u>in the second period</u>, we have the following system of equations:

$$sp(l_1' + l) = f_0\omega_0 + f\omega(1 - \eta_K z') - \frac{\theta}{2}\varphi m v^2, \qquad (37)$$

$$s'pdl = \varphi m v dv, \qquad (33)$$

where:

$$z' = \frac{I}{I_K} = \frac{\int_0^t pdt}{\int_0^{t_K} pdt} = \frac{v}{v_K},$$

z' being here already greater than unity.

The quantity $\eta_K z'$ takes into account the escape of gases through the clearance, which continues in the second period as well. As in the first period, the complete escape is proportional to the pressure impulse of the gases, which, in turn, is proportional to the velocity of the projectile.

Equation (37) can be rewritten in the following manner:

$$sp(l_1' + l) = f\omega\left[\chi_0 + 1 - \frac{\eta_K}{v_K} v - \frac{v^2}{v_{\Pi p}^2}\right], \qquad (38)$$

where:

$$\eta_K = \frac{\zeta' A s_3 I_K}{\omega}; \quad v_K = \frac{s' I_K}{\varphi m};$$

$$v_{\Pi p}^2 = \frac{2f\omega}{\varphi \theta m};$$

$$\frac{\eta_K}{v_K} = \frac{\zeta' A s_3 I_K}{\omega} \frac{\varphi m}{s' I_K} = \zeta' A \frac{\varphi}{g} \frac{q}{\omega} \frac{s_s}{s'} = \eta_K' .$$

We divide (33) by (38):

$$\frac{dl}{l_1' + l} = \frac{s}{s'} \frac{\varphi m}{f\omega} \frac{vdv}{1 + \chi_0 - \eta_K' v - \frac{v^2}{v_{\Pi p}^2}} = -\frac{s}{s'} \frac{2}{\theta} \frac{vdv}{v^2 + \eta_K' v_{\Pi p}^2 v - (1 + \chi_0) v_{\Pi p}^2}$$

or:

$$\frac{dl}{l_1' + l} = -\frac{s}{s'} \frac{2}{\theta} \frac{vdv}{v^2 + \eta_2 v - \eta_3}, \qquad (39)$$

where:

$$\eta_2 = \eta_K' v_{\Pi p}^2 - 2\zeta' A \frac{s}{\theta}\frac{s_3}{s'} - \frac{\eta_K}{\frac{v_K}{v_{\Pi p}^2}} - v_{\Pi p}\frac{\eta_K}{\frac{v_K}{v_{\Pi p}}} - \frac{\eta_K}{v_K} v_{\Pi p}^2;$$

$$\eta_3 = (1 + \chi_0') v_{\Pi p}^2 - (1 + \chi_0)\frac{2f\omega}{\varphi\theta m} - v'^2_{\Pi p} .$$

Integration of equation (39) gives:

$$\int_{l_K}^{l} \frac{dl}{l_1' + l} = -\frac{s}{s'}\frac{2}{\theta}\int_{v_K}^{v}\frac{vdv}{v^2 + \eta_2 v - \eta_3}; \tag{40}$$

$$\int_{l_K}^{l} \frac{dl}{l_1' + l} = \ln\frac{l_1' + l}{l_1' + l_K}. \tag{41}$$

We find the integral of the right-hand side by first resolving the function under the integral sign into the simplest fractions in accordance with the method proposed by Professor Drozdov.

We find the roots of the equation $v^2 + \eta_2 v - \eta_3 = \xi'(v) = 0$:

$$v = -\frac{\eta_3}{2}\left(1 \pm\sqrt{1 + 4\frac{\eta}{\eta_2^2}}\right) = -\frac{\eta_3}{2}(1 \pm b),$$

where:

$$\frac{\eta_2}{2} = \frac{f}{\theta}\frac{s_3}{s'}\zeta'_A; \quad b = \sqrt{1 + 4\frac{\eta_3}{\eta_2^2}} = \sqrt{1 + 4\gamma};$$

$$\gamma = \frac{\eta_3}{\eta_2^2} = \frac{(1 + \chi_0)v_{\Pi p}^2}{\eta'^2 (u_{\Pi p}^2)^2} = \frac{1 + \chi_0}{v_{\Pi p}^2 \cdot \eta_K'^2}, \text{ where } \eta_K' = \frac{\eta_K}{v_K};$$

$$\gamma = \frac{(1 + \chi_0)}{\eta_K}\left(\frac{v_K^2}{v_{\Pi p}^2}\right) = \frac{(1 + \chi_0)}{\eta_K} \cdot \frac{B'\theta}{2};$$

$$v_1 = -\frac{\eta_2}{2}(1 + b); \quad v_2 = -\frac{\eta_2}{2}(1 - b) = \frac{\eta_2}{2}(b - 1); \quad \eta_K = \frac{\zeta' A s_{clearance} I_K}{\omega};$$

$$v_2 - v_1 = \eta_2 b; \quad \frac{v}{\xi'(v)} = \frac{A_1}{v - v_1} + \frac{A_2}{v - v_2};$$

$$A_1 = \frac{b + 1}{2b}; \quad A_2 = \frac{b - 1}{2b};$$

$$\int_{v_K}^{v} \frac{v dv}{\xi'(v)} = \frac{b + 1}{2b}\int_{v_K}^{v} \frac{dv}{v - v_1} + \frac{b - 1}{2b}\int_{v_K}^{v} \frac{dv}{v - v_2} = \ln\left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{2b}} \cdot$$

$$\cdot \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{2b}} = \ln\frac{Z'_v}{Z'_{v_K}}. \qquad (42)$$

Upon substituting the expressions (41) and (42) into (40), we obtain:

$$\left(\frac{l_1' - l}{l_1' - l_K}\right)^{-\frac{s'}{s}\frac{\theta}{2}} = \left(\frac{l_1' + l_K}{l_1' + l}\right)^{\frac{s'}{s}\frac{\theta}{2}} = \left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{2b}} \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{2b}} =$$

$$= \frac{Z_v'}{Z_{v_K}'}$$

or, finally, we have:

$$\left(\frac{l_1' + l_K}{l_1' + l}\right)^{\frac{s'}{s}\theta} = \left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{b}} \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{b}};$$

$$l = l_1' \left[\left(1 + \frac{l_K}{l_1'}\right)\left(\frac{Z_v'}{Z_{v_K}'}\right)^{-\frac{s}{s'}\frac{2}{\theta}} - 1\right].$$

In accordance with this equation, taking definite values for $v > v_K$, we find first the values for the left-hand side, and then the corresponding values for the path of the projectile l; upon constructing a diagram, we find by interpolation or graphically the value v_D corresponding to the value l_D, whereupon, for control purposes, we check the computation once more at $v = v_D$.

The pressure is determined with the aid of the following formula:

$$p = \frac{f\omega}{s} \frac{\left(1 + \chi_0 - \frac{\eta_K}{v_K} v - \frac{v^2}{V^2 \Pi_p}\right)}{l_1' + l}.$$

Results of Computations

Basic data for 82-mm mortar; dimensions in the kg-dm-sec system:

$W_0 = 0.720$; $l_D = 10.20$; $s = 0.5277$; $s_{clearance} = 0.0082$; $f = 1120 \cdot 10^3$;
$q = 3.4$; $l_0 = 1.363$; $\omega_0 = 0.0072$; $\omega = 0.0366$; $\alpha = 0.85$;
$f_0 = 679 \cdot 10^3$; $\Lambda_D = 7.48$; $\varkappa\lambda = -0.255$; $I_K = 55$; $\Delta\xi_1' = 0.004$.
$\theta = 0.15$; $c_q = 6.16$; $A = 0.006$; $\xi_1' = 0.666$;
$\varkappa = 1.255$; $\Delta = 0.0608$;
$\delta = 1.64$;

ξ_1' is a coefficient which takes into account the shape of the escape opening; its value 0.666 has been taken from the preliminary investigation of Greten; $\varphi = 1$.

Computation of Constants

$\chi_0 = 0.1192$; $\eta_K = 0.04923$; $B' = 0.5923$;

$B_1 = 0.2994$; $\frac{B'}{B_1'} = 1.979$; $\gamma = 0.02452$;

$\beta_K = 0.2483$.

The elements of the shot are $l_m = l_K = 0.700$ dm; $p_K = p_m = 398$ kg/cm^2; $p_D = 48$ kg/cm^2; $v_D = 205.5$ m/sec.

At the same constants and $\theta = 0.20$: $p_K = p_m = 392$, $v_D = 201.0$.

In the absence of an escape of gases through the clearance: $\theta = 0.20$, $l_m = l_K = 0.678$ dm, $p_K = p_m = 435$ kg/cm^2, $p_D = 50$ kg/cm^2, $v_D = 211.5$ m/sec.

The results of the computations are found to be close to the experimental data ($p_m = 380$-390 and $v_D = 202$-205).

The best agreement between the results of the computations and the experimental data would be obtained at $\theta = 0.18$.

The results of computations presented above show that the above-derived analytical formulas make it possible to compute with good accuracy the ballistic elements of a shot from a mortar (p_K, p_m, l_K, l_m, v_K, v_m, p_D, v_D) and to construct curves for the pressures of the powder gases and for the velocity of the projectile as functions of its path.

In case only the basic charge ω_0 is present and the additional charges ω are absent, the problem is solved as for the case of the instantaneous burning of the charge, the heat loss being accounted for by considering the reduction in the propellant force of the powder f, as determined in a special apparatus.

3. EXAMPLE OF SOLUTION OF FUNDAMENTAL PROBLEM OF INTERNAL BALLISTICS FOR SMOOTH-BORE MORTARS (SIMPLIFIED METHOD).

Basic Data for 82-mm Mortar

Chamber volume W_0, dm^3	0.720
Cross-sectional area of mortar bore s, dm^2	0.5277
Cross-sectional area of clearance $s_{clearance}$, dm^2	0.0082
Coefficient characterizing shape and arrangement of clearance, ξ'	0.666
Escape coefficient A	0.006
Length of path of mortar shell through bore l_D, dm	10.20
Weight of mortar shell q, kg	3.4
Weight of charge ω, kg	0.0366
Weight of basic charge ω_0, kg	0.0072
Coefficient of consideration of secondary work φ	1.0
Propellant force of powder f, $\frac{kg \cdot dm}{kg}$	$1120 \cdot 10^3$

Propellant force of powder of basic charge f_0, $\frac{kg \cdot dm}{kg}$	679,000
Covolume α, dm^3/kg	0.85
Density of powder δ, kg/dm^3	1.64
Impulse of pressure increase at end of burning I_K	55
Form characteristics of powder: $\varkappa = 1.255$, $\varkappa\lambda = -0.255$	
Polytrope index k	1.15
$\theta = k - 1$	0.15

Basic Formulas for Computation

A. First Period.

$$z = \frac{I}{I_K} = \frac{e}{e_1}$$

$$\chi_0 = \frac{f_0\omega_0}{f\omega}$$ relative energy of basic charge;

$$s' = s - s_{clearance}$$ cross-sectional area of mortar shell at bourrelet;

$$v = \frac{s'I_K}{\varphi m} z$$ velocity of mortar shell;

$$\psi = \varkappa z + \varkappa\lambda z^2;$$

$$l = l'_{\psi av.}(Z^{-A_s} - 1)$$ expression for path of mortar shell;

$$p = \frac{f\omega}{s} \frac{\chi_0 + k_1' z - B_1' z^2}{l_\psi' + l}$$ expression for gas pressure;

$\log Z^{-1}$ is determined from the table of Professor N.F. Drozdov on the basis of the basic quantities:

$$\gamma = \frac{B_1'\chi_0}{k_1'^2}; \quad \beta = \frac{B_1'}{k_1'} z,$$

where:

$$B' = \left(\frac{s'}{s}\right)^2 \cdot \frac{s^2 I_K^2}{f\omega\varphi m} = \left(\frac{s'}{s}\right)^2 \cdot B;$$

$$B_1' = \frac{B'\theta}{2} - \varkappa\lambda;$$

$$A_s = \frac{s}{s'} \cdot \frac{B'}{B_1'};$$

$$k_1' = \varkappa - \eta_K,$$

where $\eta_K = \frac{Y_K}{\omega}$, and $Y_K = \zeta' As_{clearance}$. I_K is the quantity of gases escaping through the clearance;

$$l'_{\psi_{av.}} = l'_\psi;$$

$$l'_\psi = \frac{1}{s}\left[W_0 - \frac{\omega}{\delta}(1 - \psi) - \alpha(\omega\psi - Y) - \alpha_0\omega_0\right];$$

$$l_0 = \frac{W_0}{s}; \quad \Lambda_D = \frac{l_D}{l_0};$$

$$z_m = \frac{\varkappa - \eta_K\left(\dfrac{1 + \dfrac{\alpha p_m}{f}}{1 + \dfrac{p_m}{f\delta_1}}\right)}{\dfrac{B'\left(\dfrac{s}{s'} + \theta\right)}{1 + \dfrac{p_m}{f\delta_1}} - 2\varkappa\lambda},$$

where:

$$\frac{1}{\delta_1} = \alpha - \frac{1}{\delta}.$$

If $z_m < 1$, we have a real pressure maximum; if $z_m > 1$, the maximum is unreal, and in this case the highest actual pressure will be the pressure at the end of burning p_K.

B. Second Period.

$$v_{\Pi p}^2 = \frac{2f\omega}{\varphi\theta m};$$

$$\eta_K' = \frac{\eta_K}{v_K}, \text{ where } v_K = \frac{s' I_K}{\varphi m};$$

$$\eta_2 = \eta_K' v_{\Pi p}^2;$$

$$\eta_3 = (I + \chi_0)\, v_{\Pi p}^2; \quad \gamma = \frac{\eta_3}{\eta_2^2}; \quad b = \sqrt{1 + 4\gamma};$$

$$v_1 = -\frac{\eta_2}{2}(1 + b); \quad v_2 = \frac{\eta_2}{2}(b - 1);$$

$$\left(\frac{l_1' + l_K}{l_1' + l}\right)^{\frac{s'}{s}\theta} = \left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{b}}\left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{b}}. \qquad (a)$$

On the basis of this equation, taking definite values for $v > v_K$, we find first the values for the left-hand side, and then the corresponding values for the path of the projectile l. Upon constructing a diagram, we find by interpolation or graphically the value of v_D corresponding to the value of l_D, and, for control purposes, check the computations once more at $v = v_D$.

Or else, replacing in formula (a), v_1 and v_2 by their expressions, i.e., $v_1 = -\frac{\eta_2}{2}(1 + b)$ and $v_2 = \frac{\eta_2}{2}(b - 1)$, we find l with the aid of the following formula:

$$l = (l_1' + l_K)\left\{\left[\frac{v_K + \frac{\eta_2}{2}(b + 1)}{v + \frac{\eta_2}{2}(b + 1)}\right]^{\frac{b+1}{b}} \cdot \left[\frac{v_K - \frac{\eta_2}{2}(b - 1)}{v - \frac{\eta_2}{2}(b - 1)}\right]^{\frac{b-1}{b}}\right\}^{\frac{s}{s'}\frac{1}{\theta}} - l_1'.$$

Computation of constants (with a 50-cm slide rule).

$$\chi_0 = \frac{f_0 \omega_0}{f \omega} = \frac{679{,}000 \cdot 0.0072}{1120 \cdot 10^3 \cdot 0.0366} = 0.1192;$$

$$s' = s - s_{clearance} = 0.5277 - 0.0082 = 0.5195;$$

$$\frac{s' I_K}{\varphi m} = \frac{0.5195 \cdot 55 \cdot 98.1}{3.4} = 824.5;$$

$$\frac{\omega f}{s} = \frac{0.0366 \cdot 1120 \cdot 10^3}{0.5277} = 77{,}680;$$

$$B' = \left(\frac{s'}{s}\right)^2 \cdot \frac{s^2 I_K^2}{f \omega \varphi m} = \left(\frac{0.5195}{0.5277}\right)^2 \frac{0.5277^2 \cdot 55^2 \cdot 98.1}{1120 \cdot 10^3 \cdot 0.0366 \cdot 3.4} = 0.5747;$$

$$B_1' = \frac{B'\theta}{2} - \varkappa\lambda = \frac{0.5747 \cdot 0.15}{2} - (-0.255) = 0.2952;$$

$$A_s = \frac{s}{s'} \cdot \frac{B'}{B_1'} = \frac{0.5277}{0.5195} \cdot \frac{0.5747}{0.2952} = 1.016 \cdot 1.947 = 1.978;$$

$$Y_K = \zeta' \cdot A \cdot s_{clearance} \cdot I_K = 0.666 \cdot 0.0060 \cdot 0.0082 \cdot 55 = 0.00003277 \cdot 55 =$$
$$= 0.001802;$$

$$\eta_K = \frac{Y_K}{\omega} = \frac{0.001802}{0.0366} = 0.04923;$$

$$k_1' = \varkappa - \eta_K = 1.255 - 0.04923 = 1.2058;$$

$$\frac{B_1'}{k_1'} = \frac{0.2952}{1.2058} = 0.2448; \quad \frac{1}{\delta_1} = \alpha - \frac{1}{\delta} = 0.85 - \frac{1}{1\cdot 64} = 0.2402;$$

$$\gamma = \frac{B_1' \cdot \chi_0}{k_1'^2} = \frac{0.2952 \cdot 0.1192}{1.2058^2} = 0.02419; \quad \frac{\omega}{\delta} = \frac{0.0366}{1\cdot 64} = 0.02232;$$

$$l_0 = \frac{W_0}{s} = \frac{0.720}{0.5277} = 1.364; \quad \Lambda_D = \frac{l_D}{l_0} = 7.49; \quad \Delta = \frac{\omega}{W_0} = \frac{0.0366}{0.72} = 0.0508;$$

$$z_m = \frac{\varkappa - \gamma_K \left(\dfrac{1 + \dfrac{\alpha p_m}{f}}{1 + \dfrac{p_m}{f\delta_1}} \right)}{\dfrac{B'\left(\dfrac{s}{s'} + \theta\right)}{1 + \dfrac{p_m}{f\delta_1}} - 2\varkappa\lambda} = \frac{1.255 - 0.04923 \left(\dfrac{1 + \dfrac{0.85 \cdot 40{,}000}{1{,}120{,}000}}{1 + \dfrac{40{,}000}{1{,}120{,}000} \cdot 0.2402} \right)}{\dfrac{0.5747\left(\dfrac{0.5277}{0.5195} + 0.15\right)}{1 + \dfrac{40{,}000}{1{,}120{,}000} \cdot 0.2402} + 0.510} = 1.0257$$

$z_m > 1$, the maximum is "unreal," and the maximum pressure will in this case be the pressure p_K at the end of burning of the powder.

rm for Computation of Ballistic lements (ψ, v, l, and p) for First
(Computation with 50-cm Slide Rule).

Basic formulas	No.	Operations				
	1	z	0.3	0.5	0.7	0.9
$v = \frac{s'I_K}{\varphi m} z = 824.5z$	2	v, dm/sec	247.3	412.2	577.2	742.0
$\frac{B'_1}{k'_1} = 0.2448$	3	$\beta = \frac{B'_1}{k'_1} z$	0.07344	0.1224	0.1714	0.2203
$\varkappa = 1.255$	4	(+) $\varkappa z$	0.3765	0.6275	0.8785	1.1295
$\varkappa\lambda = -0.255$	5	$\varkappa\lambda z^2$	-0.0229	-0.0637	-0.1249	-0.206
$\psi = \varkappa z + \varkappa\lambda z^2$	6	$\psi = \varkappa z + \varkappa\lambda z^2$	0.3536	0.5638	0.7536	0.9229
	7	$1 - \psi$	0.6464	0.4362	0.2464	0.0771
$z = \frac{I}{I_K}$	8	$I = I_K \cdot z$	16.5	27.5	38.5	49.5
$\zeta' A s_{clearance} = 0.0_4 3277$	9	$Y = \zeta' A \cdot s_{clearance} \cdot I$	$0.0_3 54$	$0.0_3 90$	$0.0_2 126$	$0.0_2 16$
	10	(-) $\omega\psi$	0.0129	0.0206	0.0276	0.0338
	11	Y	0.0005	0.0009	0.0013	0.0016
	12	$\omega\psi - Y$	0.0124	0.0197	0.0263	0.0322
$\alpha_0 = \alpha = 0.85;$	13	(+) $\alpha(\omega\psi - Y)$	0.0105	0.0167	0.0223	0.027
$\frac{\omega}{\delta} = 0.02232;$	14	$\frac{\omega}{\delta}(1-\psi)$	0.0144	0.0097	0.0055	0.001
$W_0 = 0.720;$	15	$\alpha_0\omega_0$	0.0061	0.0061	0.0061	0.006
	16	a	0.0310	0.0325	0.0339	0.035
$l'_\psi = \frac{1}{s}\left[W_0 - \frac{\omega}{\delta} \cdot (1-\psi) - \alpha(\omega\psi - Y) - \alpha\omega_0\right]$	17	$W_0 - a$	0.6890	0.6875	0.6861	0.684
$a = \alpha(\omega\psi - Y) + \frac{\omega}{\delta} \cdot (1-\psi) + \alpha_0\omega_0$	18	$l'_\psi = \frac{W_0 - a}{s}$	1.306	1.303	1.300	1.298
log Z^{-1} from table on page 290 (of the origi-	19	log Z^{-1}	0.01813	0.03663	0.05759	0.080

for Computation of Ballistic lements (ψ, v, l, and p) for First Perio
(Computation with 50-cm Slide Rule).

	No.	Operations					End of burning
	1	z	0.3	0.5	0.7	0.9	1.0
	2	v, dm/sec	247.3	412.2	577.2	742.0	824.5
	3	$\beta = \frac{B_1'}{k_1'} z$	0.07344	0.1224	0.1714	0.2203	0.2448
	4	(+) $\varkappa z$	0.3765	0.6275	0.8785	1.1295	1.255
	5	$\varkappa\lambda z^2$	-0.0229	-0.0637	-0.1249	-0.2066	-0.255
	6	$\psi = \varkappa z + \varkappa\lambda z^2$	0.3536	0.5638	0.7536	0.9229	1.000
	7	$1 - \psi$	0.6464	0.4362	0.2464	0.0771	0
	8	$I = I_K \cdot z$	16.5	27.5	38.5	49.5	55.0
13277	9	$Y = \zeta' A \cdot s_{clearance} \cdot I$	0.0_354	0.0_390	0.0_2126	0.0_2162	0.0_2180
	10	(-) $\omega\psi$	0.0129	0.0206	0.0276	0.0338	0.0366
	11	Y	0.0005	0.0009	0.0013	0.0016	0.0018
	12	$\omega\psi - Y$	0.0124	0.0197	0.0263	0.0322	0.0348
	13	(+) $\alpha(\omega\psi - Y)$	0.0105	0.0167	0.0223	0.0274	0.0296
	14	$\frac{\omega}{\delta}(1-\psi)$	0.0144	0.0097	0.0055	0.0017	0
	15	$\alpha_0\omega_0$	0.0061	0.0061	0.0061	0.0061	0.0061
	16	a	0.0310	0.0325	0.0339	0.0352	0.0357
$-\psi) -$	17	$W_0 - a$	0.6890	0.6875	0.6861	0.6848	0.6843
	18	$l'_\psi = \frac{W_0 - a}{s}$	1.306	1.303	1.300	1.298	1.297
on page orfgi- r)	19	$\log Z^{-1}$	0.01813	0.03663	0.05759	0.08047	0.0928

l_K

	No.					
$'A s_{clearance} = 0.0_4 3277$	9	$Y = \zeta' A \cdot s_{clearance} \cdot I$	$0.0_3 54$	$0.0_3 90$	$0.0_2 126$	$0.0_2 162$
	10	(−) $\omega\psi$	0.0129	0.0206	0.0276	0.0338
	11	(−) Y	0.0005	0.0009	0.0013	0.0016
	12	$\omega\psi - Y$	0.0124	0.0197	0.0263	0.0322
$0 = \alpha = 0.85;$	13	(+) $\alpha(\omega\psi - \gamma)$	0.0105	0.0167	0.0223	0.0274
$= -0.02232;$	14	(+) $\frac{\omega}{\delta}(1-\psi)$	0.0144	0.0097	0.0055	0.0017
$W_0 = 0.720;$	15	(+) $\alpha_0\omega_0$	0.0061	0.0061	0.0061	0.0061
	16	a	0.0310	0.0325	0.0339	0.0352
$l'_\psi = \frac{1}{s}\left[W_0 - \frac{\omega}{\delta} \cdot (1-\psi) - \alpha(\omega\psi - Y) - a\omega_0\right]$	17	$W_0 - a$	0.6890	0.6875	0.6861	0.6848
$a = \alpha(\omega\psi - Y) + \frac{\omega}{\delta} \cdot (1-\psi) + \alpha_0\omega_0$	18	$l'_\psi = \frac{W_0 - a}{s}$	1.306	1.363	1.300	1.298
$\log Z^{-1}$ from table on page 290 (of the original - Editor)	19	$\log Z^{-1}$	0.01813	0.03663	0.05759	0.08047
$\gamma = 0.02419$	20	$A_s \log Z^{-1}$	0.03586	0.07245	0.1139	0.1592
$A_s = 1.978$	21	Z^{-A_s}	1.086	1.181	1.300	1.443
	22	(+) $l = l'_\psi \cdot (Z^{-A_s} - 1)$	0.1123	0.2358	0.390	0.5750
	23	(+) l'_ψ	1.306	1.303	1.300	1.298
	24	$l + l'_\psi$	1.418	1.5388	1.690	1.873
$p = \frac{f\omega}{s} \frac{\chi_0 + k'_1 z - B'_1 z^2}{l'_\psi + l}$	25	(+) χ_0	0.1192	0.1192	0.1192	0.1192
	26	(+) $k'_1 z$	0.3617	0.6029	0.8440	1.0852
	27	(−) $\chi_0 + k'_1 z$	0.4809	0.7221	0.9632	1.2044
	28	(−) $B'_1 z^2$	0.0266	0.0738	0.1446	0.2391
$\frac{f\omega}{s} = 77{,}680$	29	$\chi_0 + k'_1 z - B'_1 z^2$	0.4543	0.6483	0.8186	0.9653
	30	p, kg/cm^2	249.0	327.0	376.0	400.0

	$t_K \cdot z$	16.5	27.5	38.5	49.5	55.0
9	$Y = \zeta' A \cdot s_{clearance} \cdot I$	0.0_354	0.0_390	0.0_2126	0.0_2162	0.0_2180
10	$(-)\begin{cases} \omega\psi \end{cases}$	0.0129	0.0206	0.0276	0.0338	0.0366
11	$\quad Y$	0.0005	0.0009	0.0013	0.0016	0.0018
12	$\omega\psi - Y$	0.0124	0.0197	0.0263	0.0322	0.0348
13	$(+)\begin{cases} \alpha(\omega\psi - \gamma)' \end{cases}$	0.0105	0.0167	0.0223	0.0274	0.0296
14	$\frac{\omega}{\delta}(1-\psi)$	0.0144	0.0097	0.0055	0.0017	0
15	$\alpha_0\omega_0$	0.0061	0.0061	0.0061	0.0061	0.0061
16	a	0.0310	0.0325	0.0339	0.0352	0.0357
17	$W_0 - a$	0.6890	0.6875	0.6861	0.6848	0.6843
18	$l'_\psi = \frac{W_0 - a}{s}$	1.306	1.303	1.300	1.298	1.297
19	$\log Z^{-1}$	0.01813	0.03663	0.05759	0.08047	0.0928
20	$A_s \log Z^{-1}$	0.03586	0.07245	0.1139	0.1592	0.1835
21	Z^{-A_s}	1.086	1.181	1.300	1.443	1.526
22	$(+)\begin{cases} l = l'_\psi \cdot (Z^{-A_s} - 1) \end{cases}$	0.1123	0.2358	0.390	0.5750	0.6822
23	l'_ψ	1.306	1.303	1.300	1.298	1.297
24	$l + l'_\psi$	1.418	1.5388	1.690	1.873	1.979
25	$(+)\begin{cases} \chi_0 \end{cases}$	0.1192	0.1192	0.1192	0.1192	0.1192
26	$k'_1 z$	0.3617	0.6029	0.8440	1.0852	1.2058
27	$(-)\begin{cases} \chi_0 + k'_1 z \end{cases}$	0.4809	0.7221	0.9632	1.2044	1.3250
28	$B'_1 z^2$	0.0266	0.0738	0.1446	0.2391	0.2952
29	$\chi_0 + k'_1 z - B'_1 z^2$	0.4543	0.6483	0.8186	0.9653	1.0298
30	p, kg/cm^2	249.0	327.0	376.0	400.0	404.2

Computation of Second Period

Computation of Constants for the Second Period

$$v_{\Pi p}^{2} = \frac{2f\omega}{\varphi\theta_{m}} = \frac{2\cdot 1{,}120{,}000\cdot 0.0366\cdot 98.1}{0.15\cdot 3.4} = 15{,}770{,}000;$$

$$\eta_K' = \frac{\eta_K}{v_K} = \frac{0.04923}{824\cdot 5} = 0.0_{4}5971;$$

$$\eta_2 = \eta_K' \cdot v_{\Pi p}^{2} = 0.0_{4}5971\cdot 1577\cdot 10^{4} = 941.6;$$

$$\eta_3 = (1 + \chi_0)\, v_{\Pi p}^{2} = 1.1192\cdot 1577\cdot 10^{4} = 17{,}650{,}000;$$

$$\gamma = \frac{\eta_3}{\eta_2^{2}} = \frac{17{,}650{,}000}{941.6^{2}} = 19.91;$$

$$b = \sqrt{1 + 4\gamma} = \sqrt{1 + 4\cdot 19.91} = 8.978;$$

$$v_1 = -\frac{\eta_2}{2}(1 + b) = \frac{-941.6}{2}(1 + 8.978) = -4698;$$

$$v_2 = \frac{\eta_2}{2}(b - 1) = \frac{941.6}{2}\cdot 7\cdot 978 = 3756;$$

$$\frac{b + 1}{b} = \frac{9.978}{8.978} = 1.111;$$

$$\frac{b - 1}{b} = \frac{7.978}{8.978} = 0.8886;$$

$$\frac{s}{s'}\frac{1}{\theta} = \frac{0.5277}{0.5195}\cdot\frac{1}{0.15} = 6.770;$$

$$\frac{\eta_K}{v_K} = \frac{0.04923}{824.5} = 0.00005971.$$

Form for Computation of Elements for Second Period

Basic formulas	No.	Operations				Muzzle face
$\left(\frac{l_1 + l_K}{l_1' + l}\right)^{\frac{s'}{s}\theta} =$	1					
		(-) v	1200	1500	1800	2052
		v_1	-4698	-4698	-4698	-4698
$= \left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{b}} \cdot$	2					
$\cdot \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{b}}$						
$v_1 = -\frac{\eta_2}{2}(1 + b) = -4698$	3	$v - v_1$	5898	6198	6498	6750
	4	(-) v_K	824.5	824.5	824.5	824.5
	5	v_1	-4698	-4698	-4698	-4698
$v_K = \frac{s' I_K}{\varphi m} = 824.5$	6	$v_K - v_1$	5522.5	5522.5	5522.5	5522.5
	7	$\frac{v - v_1}{v_K - v_1}\ldots$	1.068	1.122	1.176	1.222
	8	$\log \frac{v - v_1}{v_K - v_1}\ldots$	0.0285	0.0500	0.0704	0.0871
	9	$\frac{b+1}{b} \log \frac{v - v_1}{v_K - v_1}\ldots$	0.03166	0.05555	0.07821	0.0968
$\frac{b + 1}{b} = 1.111$	10	$\left(\frac{v - v_1}{v_K - v_1}\right)^{\frac{b+1}{b}}$	1.076	1.137	1.198	1.249

(cont'd)

Basic formulas	No.	Operations				Muzzle face
$v_2 = \frac{\eta_2}{2}(b - 1) = 3756$	11 12	$(-)\begin{cases} v \\ v_2 \end{cases}$	1200 +3756	1500 3756	1800 3756	2052 3756
	13	$v - v_2$	-2556	-2256	-1956	-1704
	14 15	$(-)\begin{cases} v_K \\ v_2 \end{cases}$	824.5 3756	824.5 3756	824.5 3756	824.5 3756
	16	$v_K - v_2$	-2931.5	-2931.5	-2931.5	-2931.5
$\frac{b - 1}{b} = 0.8886$	17	$\frac{v - v_2}{v_K - v_2}\ldots$	0.8719	0.7696	0.6672	0.5813
	18	$\log \frac{v - v_2}{v_K - v_2}$	$\bar{1}.9404$ -0.0596	$\bar{1}.8862$ -0.1138	$\bar{1}.8242$ -0.1758	$\bar{1}.7644$ -0.2356
	19	$\frac{b - 1}{b} \log \frac{v - v_2}{v_K - v_2}$	0.05296 $\bar{1}.9470$	-0.1011 $\bar{1}.8989$	-0.1526 $\bar{1}.8438$	-0.2094 $\bar{1}.7906$
$\frac{s}{s'}\frac{1}{\theta} = 6.77$	20	$\left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{b}}$	0.8851	0.7923	0.6979	0.6175
	21	$\Gamma = \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b+1}{b}} \cdot \left(\frac{v - v_2}{v_K - v_2}\right)^{\frac{b-1}{b}}$	0.9524	0.9008	0.8361	0.7712
	22	$\log \Gamma$	$\bar{1}.9788$ -0.0212	$\bar{1}.9546$ -0.0454	$\bar{1}.9223$ -1.0777	$\bar{1}.8872$ -0.1128

(cont'd)

Basic formulas	No.	Operations				Muzzle face
$p = \frac{f\omega}{s} \frac{1 + \chi_0 - \frac{\eta_K}{v_K} v - \frac{v^2}{v^2_{np}}}{l'_1 + l}$	23	$\frac{s}{s'} \frac{1}{\theta} \log \Gamma \ldots$	-0.1435 $\bar{1}$.8565	-0.3073 $\bar{1}$.6927	-0.5260 $\bar{1}$.4740	-0.7636 $\bar{1}$.2364
$l'_1 = 1.297$	24	$\frac{s}{\Gamma s'} \frac{1}{\theta} \ldots$	0.7186	0.4928	0.2979	0.1724
$l'_1 + l_K = 1.297 + 0.682 = 1.979$	25	$l'_1 + l_K$	1.979	1.979	1.979	1.979
$\chi_0 = 0.1192$	26	(-) $\frac{l'_1 + l_K}{\Gamma \frac{s}{s'} \frac{1}{\theta}}$	2.754	4.016	6.643	11.479
	27	$l'_1 \ldots$	1.297	1.297	1.297	1.297
$\frac{\eta_K}{v_K} = 0.0_4 5971$	28	l	1.457	2.719	5.346	10.182
	29	$l'_1 + l$	2.754	4.016	6.643	11.479
	30	(-) $1 + \chi_0$	1.1192	1.1192	1.1192	1.1192
	31	$\frac{\eta_K}{v_K} \cdot v$	0.0716	0.0896	0.1075	0.1225
$\frac{f\omega}{s} = 77,680$	32	(-) $1 + \chi_0 - \frac{\eta_K}{v_K} \cdot v$	1.0476	1.0296	1.0117	0.9967
	33	$\frac{v^2}{v^2_{np}} \ldots$	0.0913	0.1427	0.2055	0.2671
	34	$1 + \chi_0 - \frac{\eta_K v}{v_K} - \frac{v^2}{v^2_{np}}$	0.9563	0.8869	0.8062	0.7296
	35	p, kg/cm^2	270	172	94.0	49.0

The results of the computation are presented in fig. 172.

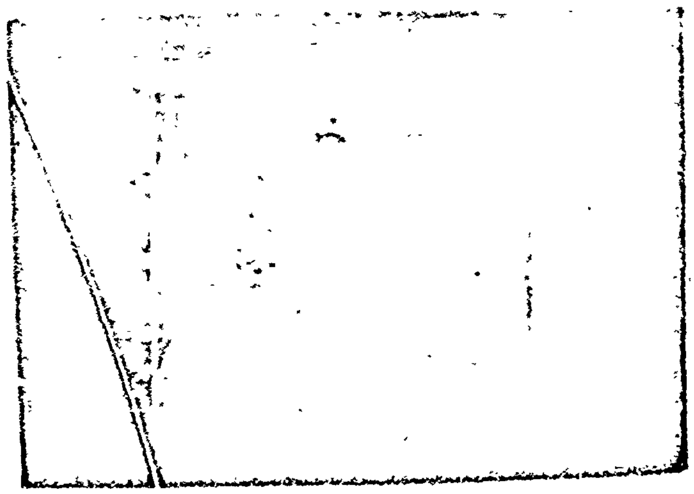

Fig. 172 - p-l and v-l Curves for Mortar.

1) kg/cm^2; 2) p-l and v-l curves for 82-mm mortar; 3) m/sec.

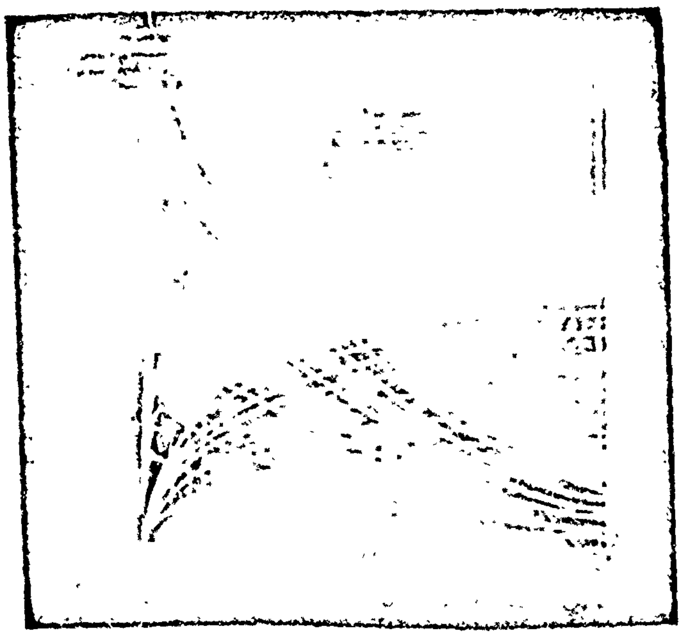

Fig. 172-a - p-l and v-l Curves for Mortar with Various Charges.

1) kg/cm^2; 2) m/sec; 3) designations; 4) charge nos.

Fundamental Ballistic Data for Mortars.

c_q	6.8	6.17	6.53	9.25	
C_t	3.13	12.6	34.1	33.1	
Δ	0.028	0.061	0.151	0.140	
p_m	300	450	850	1000	
ω/q	0.0053	0.0129	0.0387	0.0281	
W_0/d^3	1.29	1.31	1.67	1.87	
$\frac{\eta\omega}{L'_{KH}\cdot d}$	10.3	11.2	11.45	11.05	$\sim$ const
$\eta_D = \frac{p_{av.}}{p_m}$	0.195	0.286	0.530	0.457	
W_0/q	0.190	0.212	0.256	0.202	
l_0/d	1.64	1.66	2.13	2.37	
Δ'_0 (*)	0.67	0.56	0.64	0.64	
Λ_D	4.15	7.50	4.53	3.87	

(*) Δ'_0 is the loading density of the basic charge in relation to the chamber of the tail cartridge.

SECTION TWELVE - GUNS WITH CONICAL BORE

INTRODUCTION

Guns with a conical bore had been proposed as experimental models as far back as the 1870's. After the First World War, the German engineer Herlich conducted firing tests from a rifle with a conical bore. In these tests, there was obtained an initial bullet velocity that was considerably higher than the usual velocity, as a result of which the armor-piercing effect was sharply increased.

In the course of the Second World War, use was made in the German army of conical guns of various calibers, which were employed principally as antitank artillery. The following guns were used: an antitank gun with a 28-mm entrance caliber and a 20-mm exit caliber (28/20), giving a projectile velocity of 1400 m/sec; a 42/28 antitank gun of the same type; and a 75/55 cylindrical-conical gun (v_D' = about 1250 m/sec), whose barrel consisted of a 75-mm rifled cylindrical tube of the usual type, followed by a smooth conical part with the diameters 75/55, and a smooth cylindrical end piece of 55-mm caliber. The projectile had two skirt bands: a thinner directing band in front and a thicker rotating band in the rear. A section through the armor-piercing projectile for the 75/55 gun is shown in fig. 173.

Firing from a conical barrel is in principle analogous to firing from an ordinary gun with a subcaliber projectile. For this reason, we shall discuss at the outset the possibility of increasing the velocity of the projectile by reducing its weight through a transition to a subcaliber model.

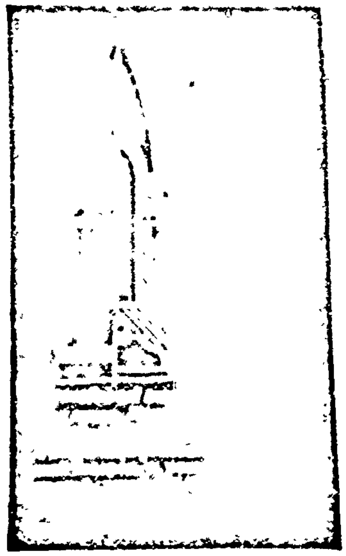

Fig. 173 - Armor-Piercing Projectile for 75/55 Conical Gun.

In recent years, and especially during the Great Patriotic War, attempts have been made to increase the armor-piercing ability of the projectile by increasing its velocity through a reduction in its weight.

Let us determine to what extent the velocity of a projectile in a given gun will change at a predetermined maximum pressure p_m if the weight of the projectile q is changed.

For an ordinary projectile; let us designate its weight as q_1', its initial velocity as v_D', the pressure impulse of the powder as I_K', and the thickness of the powder as $2e_1' = I_K' \cdot 2u_1'$. Let the new weight of the projectile be $q'' < q'$; the problem is to determine the changed velocity v_D''.

We have the simplest case by accepting the conditions that p_m and Δ (or ω) remain unchanged.

From the formula for the second period, we have:

$$\frac{\varphi q v_D^2 \theta}{2gf\omega} = 1 - \frac{(\Lambda_K + 1 - \alpha\Delta)^\theta}{(\Lambda_D + 1 - \alpha\Delta)^\theta}\left[1 - \frac{B\theta}{2}(1 - z_0)^2\right] = 1 - \frac{K^\theta}{(\Lambda_D + 1 - \alpha\Delta)^\theta}; \qquad (43)$$

where:

$$K = (\Lambda_K + 1 - \alpha\Delta)\left[1 - \frac{B\theta}{2}(1 - z_0)^2\right]^{\frac{1}{\theta}}.$$

Under the condition of constancy of the values for p_m, Δ, and ω, we have B and Λ_K = const, K = const; for this reason, the left-hand side of the expression (43) also remains unchanged (r'_D = const).

Consequently, discarding the constant quantities, we obtain the following correlation:

$$\varphi q v_D^2 = \left(a + b\frac{\omega}{q}\right) q v_D^2 = \text{const}, \tag{44}$$

from which:

$$\left(\frac{v''_D}{v'_D}\right)^2 = \frac{\varphi' q'}{\varphi'' q''} = \frac{q'}{q''}\,\frac{a + b\frac{\omega}{q'}}{a + b\frac{\omega}{q''}}. \tag{45}$$

The condition (44) at ω = const is equivalent to the condition:

$$\frac{\varphi q v_D^2}{2g\omega} = \varphi\eta_\omega = \text{const},$$

and, since the quantity $\varphi = a + b\frac{\omega}{q}$ increases as the weight of the projectile decreases, it follows that, under the imposed conditions of maintaining p_m, Δ, and ω constant, the coefficient of utilization of the charge η_ω will be somewhat lower with the lighter projectile than with the ordinary projectile.

Thus:

$$v''_D = v'_D\sqrt{\frac{q'}{q''}\,\frac{\varphi'}{\varphi''}}; \tag{46}$$

$$\eta''_{\omega} = \eta'_{\omega} \frac{\varphi'}{\varphi''}.$$

From the condition B = const, we obtain the following additional condition:

$$\frac{I_K^2}{\varphi q} = \text{const} \qquad (47)$$

or:

$$I_K'' = I_K' \sqrt{\frac{\varphi''}{\varphi'} \frac{q''}{q'}}.$$

It follows from (46) and (47) that:

$$I_K'' v_D'' = I_K' v_D' = \text{const}.$$

The formula makes it possible to select the weight of projectile q" necessary to obtain in the given gun the required initial velocity v_D''.

How will V_{max} change as the light-weight projectile is adopted?

$$V_{max} = \frac{q}{Q_{CT}} \frac{1 + \beta \frac{\omega}{q}}{1.15} v_D,$$

where:

$$\beta \approx \frac{C_1}{v_D} = \frac{\text{const}}{v_D};$$

β being the coefficient of secondary action of the gases.

We change the weight of the projectile, retaining ω = const.

$$\frac{v''_D}{v'_D} = \sqrt{\frac{q'}{q''}\,\frac{\varphi'}{\varphi''}}; \quad \beta\,\frac{\omega}{q} = \frac{C_1\omega}{q v_D};$$

$$\frac{V''_{max}}{V'_{max}} = \frac{q''}{q'}\;\frac{1 + \dfrac{C_1\omega}{v''_D q''}}{1 + \dfrac{C_1\omega}{v'_D q'}}\;\frac{v''_D}{v'_D} = \frac{q''v''_D + C_1\omega}{q'v'_D + C_1\omega} =$$

$$= \frac{q'v'_D\sqrt{\dfrac{\varphi'}{\varphi''}\,\dfrac{q''}{q'}} + C_1\omega}{q'v'_D + C_1\omega} = \frac{\sqrt{\dfrac{\varphi'}{\varphi''}\,\dfrac{q''}{q'}} + \beta'\,\dfrac{\omega}{q'}}{1 + \beta'\,\dfrac{\omega}{q'}}.$$

Since:

$$\varphi'q'' < \varphi''q',$$

it follows that:

$$V''_{max} : V'_{max} < 1.$$

Consequently, in adopting a light-weight type projectile while retaining the same weight of the charge, in spite of the increase in the velocity of the projectile, the maximum recoil velocity decreases, so that the load on the gun mount also decreases.

Thus, the obtaining of increased projectile velocities by reducing the weight of the projectile is a fully justified and practically realizable measure.

Let a projectile with a weight coefficient $c_q' = 15.0$ have $v_D' =$ $= 1000$ m/sec at $\omega/q = 0.45$. If $\varphi = 1.03 + \frac{1}{3}\frac{\omega}{q}$, $\varphi' = 1.18$.

We adopt a light-weight projectile with a weight coefficient $c_q'' =$ $7.5 = \frac{1}{2} c_q'$. Then $\omega/q'' = 0.90$, $\varphi'' = 1.03 + \frac{1}{3} \cdot 0.90 = 1.33$.

$$v_D'' = 1000 \sqrt{\frac{1.18}{1.33} \cdot \frac{15.0}{7.5}} = 1000 \cdot 1.33 = 1330 \text{ m/sec}.$$

If $\eta_\omega' = 130$, then:

$$\eta_\omega'' = 130 \frac{1.18}{1.33} = 115.3 \text{ tm/kg};$$

$$I_K'' = I_K'' \frac{1}{1.33} = 0.752.$$

Thus, if the weight of the projectile is halved, the velocity in the case under consideration increases by 33%, and the thickness of the powder decreases by 25% (the same p_m and Δ being retained).

Let us consider the condition on the basis of which it is possible to determine the weight of the projectile necessary to obtain a predetermined v_D'' in firing from a given gun.

From the condition (45), we have:

$$\left(\frac{v_D''}{v_D'}\right)^2 = \frac{a + b\frac{\omega}{q'}}{a + b\frac{\omega}{q''}} \frac{q'}{q''} = \frac{aq' + b\omega}{aq'' + b\omega}.$$

From this, we obtain:

$$q'' = \frac{q'}{a}\left[\varphi'\left(\frac{v_D'}{v_D''}\right)^2 - b\,\frac{\omega}{q'}\right]. \qquad (48)$$

CHAPTER 1 - FUNDAMENTAL CHARACTERISTICS AND BALLISTIC PROPERTIES OF BARREL WITH CONICAL BORE

In order to slowly lose velocity in flight, a projectile must be "heavy," i.e., must have the greatest possible weight coefficient $c_q = q/d^3$ or transverse load q/s. In order to attain a predetermined initial velocity in the bore after as short a path as possible, a projectile must be "light," i.e., must have the smallest possible weight coefficient c_q.

These two mutually contradictory requirements make it possible to reconcile barrels with a conical or cylindrical-conical bore.

Let d_0 be the entrance caliber of the conical bore and d_D its exit caliber, where $d_D < d_0$. In such a bore, the projectile, by having with respect to the entrance caliber a small coefficient $c_{q_0} = q/d_0^3$ and always retaining it smaller than $c_{q_D} = q/d_D^3$ until it is ejected from the bore, will acquire a predetermined velocity v_D after a considerably shorter path than a projectile of the same weight in a cylindrical bore with a caliber d_D equal to the exit caliber of the conical bore; but, as this projectile is ejected, it will already have a large weight coefficient $c_{q_D} = q/d_D^3$ with respect to the exit caliber d_D and will be advantageous for flight in the air.

The solution of the problem of the clarification of the fundamental ballistic properties of a conical bore must be sought in a comparison of cylindrical guns of different calibers firing a projectile possessing a given weight, and this problem is easily solved by theoretical means.

As a matter of fact, it is known from the general relations encountered in ballistic design that, at identical Δ, ω/q, p_m, and v_D, the lengths of the bore L_{KH} and of the chamber l_0, expressed in calibers, and the thicknesses of the powder in relation to the caliber are proportional to the projectile-weight coefficients c_q, and the absolute

values of the same quantities are proportional to the values for q/s (transverse load).

The fundamental relations of internal ballistics for cylindrical bores give:

$$\frac{W_{KH}}{q} = \frac{W_0}{q}\left\{\frac{K(p_m,\Delta)}{(1 - r')^{\frac{1}{\theta}}} + \alpha\Delta\right\}$$

or:

$$\frac{L'_{KH}}{d} = \frac{l_0}{d}\left\{\frac{K(p_m,\Delta)}{(1 - r')^{\frac{1}{\theta}}} + \alpha\Delta\right\}.$$

The expression enclosed in brackets equals $\Lambda_D + 1$;

$$\frac{l_0}{d} = \frac{W_0}{sd} = \frac{W_0}{n_s d^3} = \frac{\omega}{q}\,\frac{1}{n_s\Delta}\,\frac{q}{d^3} = \frac{\omega}{q}\,\frac{c_q}{n_s\Delta}.$$

At predetermined p_m, v_D, ω/q and Δ, the expression in the brackets is a constant quantity, and l_0/d is proportional to c_q; consequently, both $\frac{L'_{KH}}{d} = \frac{l_0}{d}\left\{\Lambda_D + 1\right\}$ and $\frac{l_D}{d} = \frac{l_0}{d}\left\{\Lambda_D\right\}$ are also proportional to the quantity c_q.

Since:

$$\frac{I_K}{d} = \sqrt{\frac{f}{g}}\,\frac{c_q}{n_s}\sqrt{B\varphi\frac{\omega}{q}},$$

it follows that, at predetermined p_m and Δ, the quantity B = const, and at a predetermined ω/q, the quantity φ is also constant. Consequently, the relative pressure impulse is likewise proportional to the weight

coefficient c_q.

The larger the caliber of a gun at a given weight of the projectile, the smaller is l_K/d and the thinner is the powder necessary to ensure attainment of the same maximum pressure p_m in the presence of the same charge.

It further follows from this that the absolute values of l_0, l_D, L'_{KH}, and l_K are directly proportional to the transverse load q/s.

The relation between c_q and q/s for the entrance and exit calibers will be expressed as follows:

$$c_{q_0} = c_{q_D}\left(\frac{d_D}{d_0}\right)^3; \quad \frac{q}{s_0} = \frac{q}{s_D}\left(\frac{d_D}{d_0}\right)^2.$$

Since usually $d_0/d_D = 1.35\text{-}1.40$, it follows that:

$$\left(\frac{d_0}{d_D}\right)^3 = (1.40\ldots1.35)^3 = 2.75\ldots2.46; \left(\frac{d_D}{d_0}\right)^3 = 0.363\text{-}0.407;$$

$$\left(\frac{d_0}{d_D}\right)^2 = 1.96\ldots1.82; \quad \left(\frac{d_D}{d_0}\right)^2 = 0.51\text{-}0.55.$$

Consequently, at $d_0/d_D = 1.4$, a projectile of a given weight will attain a predetermined velocity v_D in a cylindrical gun of caliber d_0 after traversing a path nearly twice as short as in a similar cylindrical gun of caliber d_D.

At a given chamber volume, both the bore volumes and the quantities Λ_D will be identical. At a given p_m, the p-Λ and v-Λ curves will coincide.

If now, while retaining the weight of the projectile, the chamber and bore volumes, and consequently also $\Lambda_D = W_D/W_0$ constant, a gradual transition is made in cylindrical guns from the larger to the smaller caliber, the lengths of the chambers and bores, as well as the weight coefficients c_q, will gradually increase. Since, in this connection, Δ, q, ω/q, p_m, and v_D remain the same, it follows that, for such cylindrical guns, the v-Λ or v-W curves coincide not only for c_{q_0} and c_{q_D}, but also for all intermediate calibers and c_q.

This is a fundamental property of ballistically similar guns of different calibers, which makes it possible to explain the properties of the v-l and p-l curves for a conical barrel.

As a matter of fact, in a conical barrel of the same volume, with the same chamber volume, and with the same value for $\Lambda_D = W_D/W_0$, there is accomplished a continuous transition from a cylindrical barrel with the initial entrance caliber d_0 and $c_{q_0} = \frac{q}{d_0^3}$ to a cylindrical barrel with the exit caliber d_D and $c_{q_D} = q/d_D^3$. Since there has already been established the identity of the curves for the velocity of the projectile as a function of $\Lambda = W/W_0$ for all cylindrical barrels with gradually diminishing calibers, it is possible to conclude that, at a given weight of the projectile, the velocity curve v-Λ for the conical bore at the same Δ, ω/q, φ, and p_m will coincide with the same curves for all cylindrical barrels of various calibers, but having the same volume.

This is one of the fundamental assumptions made by us with regard to the ballistic properties of a conical bore. At the same volume of the bore and of its working part, its length is smaller than the length of a cylindrical bore of caliber d_D and greater than the length of a

similar bore of caliber d_0. This is clear from the sketch presented in fig. 174.

Fig. 174 - Sketch of Conical and Cylindrical Bores.

As will be shown subsequently, the pressure curve in the conical bore as a function of relative volume, will not coincide with the pressure curves for the same bores having a cylindrical shape; after reaching the maximum, this curve will be disposed higher than the p-Λ curve for cylindrical bores, and the end of burning at the same maximum pressure will occur earlier in the conical bore than in the cylindrical one:

$$\Lambda_{K_{con.}} < \Lambda_{K_{cyl.}}$$

1. DESIGNATIONS AND GEOMETRIC CHARACTERISTICS OF CONICAL BORE.

Entrance caliber.............	d_0
Exit caliber.................	d_D
Angle of conicity............	β
Length of path of projectile..	l_D
Total length of cone..........	$h_K = l_D \cdot \frac{d_0}{d_0 - d_D} = \frac{d_0}{2}\cot \beta$
Total volume of cone to apex..	$W_{con.}$
Volume of working part of cone.	W_D

Total bore volume including chamber..... $W_{KH} = W_0 + W_D$

Total relative volume of conical bore... $\Lambda_D = \frac{W_D}{W_0}$

Fig. 175 - Geometric Data of Conical Bore.

Let us introduce the relative diameter $y = d/d_0$. All remaining characteristics are expressed very simply as functions of this quantity:

$$y = \frac{d}{d_0} = \frac{h_K - l}{h_K} = 1 - \frac{l}{h_K}.$$

From this:

$$l = h_K(1 - y); \quad l_D = h_K(1 - y_D);$$

$$\frac{s}{s_0} = \left(\frac{d}{d_0}\right)^2 = y^2; \quad \frac{s_{av.}}{s_0} = \frac{1 + y + y^2}{3} \approx y;$$

$$W = s_0\left(\frac{1 + y + y^2}{3}\right) l = \frac{s_0 h_K}{3}(1 + y + y^2)(1 - y) =$$

$$= \frac{s_0 h_K}{3}(1 - y^3) = W_{con.}(1 - y^3);$$

$$\Lambda_D = \frac{W_D}{W_0} = \frac{s_0 h_K}{3 s_0 l_0}(1 - y_D^3) = \frac{h_K}{3 l_0}(1 - y_D^3).$$

Since we shall subsequently adopt $\Lambda = W/W_0$ as the independent variable, we find as a function of the latter:

$$y = \sqrt[3]{1 - \frac{W}{W_{con.}}} = \sqrt[3]{1 - \frac{\Lambda}{\Lambda_{con.}}},$$

where $\Lambda_{con.} = W_{con.}/W_0$.

The remaining quantities, as previously, are expressed in terms of y:

$$l = h_K(1 - y); \; s = s_0 y^2; \; s_{av.} = s_0 \frac{1 + y + y^2}{3}.$$

The system of equations for the conical bore differs in no way externally from the equations for the cylindrical bore; only the value for the cross-sectional area s entering into the equations is variable, and this complicates the solution of the problem.

For an exact solution, it becomes necessary to resort to the method of numerical integration or resolution into a series.

However, the coincidence of the projectile-velocity curves as a function of Λ for the conical and cylindrical bores makes it possible approximately, but with a sufficient degree of precision, to solve the problem for the conical barrel in the final form by introducing an average value for s (which is possible in the presence of a slight conicity).

In this connection, we take for comparison a cylindrical barrel with a caliber equal to the entrance caliber d_0 and with the same system characteristics:

$$W_0, \; W_D, \; q, \; \frac{\omega}{q}, \; \Delta, \; \varphi, \; I_K, \; f, \; \alpha, \; \delta, \; \theta \text{ and } p_0.$$

Let us write down the system of fundamental relations.

$spdt = \varphi m dv$ .... (1) Equation of motion;

$de = u_1 pdt$ .... (2) Law of burning rate;

$p(W_\psi + W) = f\omega\psi - \frac{\theta}{2}\varphi m v^2$ .. (3) Equation of transformation of energy.

Solving (3) with respect to p, and introducing Λ and Λ_ψ, we obtain:

$$p = f\omega \frac{\psi - \frac{v^2}{v_{np}^2}}{W_\psi + W} = f\Delta \frac{\psi - \frac{v^2}{v_{np}^2}}{\Lambda_\psi + \Lambda}, \tag{49}$$

where:

$$\Lambda_\psi = 1 - \frac{\Delta}{\delta} - \left(\alpha - \frac{1}{\delta}\right)\Delta\psi;$$

$$\frac{s}{s_0} = \left(1 - \frac{W}{W_{con.}}\right)^{\frac{2}{3}} = \left(1 - \frac{\Lambda}{\Lambda_{con.}}\right)^{\frac{2}{3}}$$

is the dependence of the cross-sectional area upon the relative bore volume;

$$W_{con.} = \frac{s_0 h_K}{3} = \frac{s_0}{3}\frac{d_0}{2}\cot\beta.$$

$$\psi = \psi_0 + \varkappa\sigma_0 x + \varkappa\lambda x^2 \ (*)$$

is the law of inflow of the gases.

From (1) and (2), as usual, we obtain:

$$sde = u_1\varphi m dv;$$

$$dv = \frac{s}{\varphi m}\frac{e_1}{u_1} dz = \frac{sI_K}{\varphi m} dx. \tag{50}$$

In contrast with the cylindrical barrel, in this case s is a variable which is not directly connected with either x or v; but the property, assumed above, of the coincidence of the $v = f(\Lambda)$ curves for the cylindrical and conical barrels at equal p_m, W_0, and Λ_D makes it possible to establish s as a function of v for the conical bore with the aid of the $v = f(\Lambda)$ curve obtained for the cylindrical barrel.

By introducing into equation (50) the quantity for the entrance cross section s_0, integrating, and taking s/s_0 on the right-hand side outside the integral sign in the form of an average value, we obtain:

$$v = \frac{s_0 I_K}{\varphi m} \frac{s_{av.}}{s_0} x. \tag{51}$$

For the cylindrical barrel with the same cross section s_0, we have the usual relation (in which all elements are marked by '):

$$v' = \frac{s_0 I_K}{\varphi m} x',$$

φ and I_K being the same as in the preceding equation. Since for a given value of Λ:

$$v = v',$$

it follows that:

$$\frac{s_{av.}}{s_0} x = x'$$

or:

$$x = \frac{x'}{\frac{s_{av.}}{s_0}} > x'. \tag{52}$$

It is seen from this that, at one and the same value of v for the conical and cylindrical bores, and at the same values of I_K and φ, the relative thickness of the burnt powder x for the conical barrel is greater than the corresponding quantity x' for the cylindrical barrel: $x > x'$. Consequently, on the basis of formula (49), there follow the relations stated below.

(a) For a conical barrel with a variable cross section from s_0 to s_D:

$$p = f\Delta \frac{\psi - \frac{v^2}{v^2_{np}}}{\Lambda_{\psi'} + \Lambda};$$

(b) For cylindrical bores with a cross section s_0 = const or s_D = const:

$$p' = f\Delta \frac{\psi' - \frac{v'^2}{v^2_{np}}}{\Lambda'_{\psi'} + \Lambda'}.$$

Since, from (52), $x > x'$; from (*), $\psi > \psi'$ and $\Lambda_\psi < \Lambda'_\psi$; and $v = v'$ and $\Lambda = \Lambda'$; it follows that $p > p'$.

We obtain the following fundamental conclusion, which characterizes the ballistic properties of the conical barrel: under identical loading conditions (W_0, ω/q, Δ, I_K), and in the presence of identical values for the working volume W and the projectile velocity v, the burnt part of the charge ψ and the gas pressure are greater in the conical barrel than in the cylindrical bore with the cross section s_0. The difference is the greater the greater the conicity of the bore.

GRAPHIC NOT REPRODUCIBLE

Fig. 176 - p-W Pressure Curves for Conical Bore.

Consequently, under loading conditions identical with those in a cylindrical barrel with the same W_0, W_D, and s_0, the gas-pressure curve in a conical barrel, expressed as a function of W, has a more progressive character than in the cylindrical barrel; and since the average pressure in the former is greater than in the latter, the end of burning of the powder will occur in the former sooner, at a smaller Λ_K, than in the latter.

2. RELATION OF POWDER THICKNESSES IN CONICAL AND CYLINDRICAL BORES UNDER EQUAL MAXIMUM PRESSURES.

It has been shown that, at identical entrance calibers d_0, under identical loading conditions (Δ, ω/q, W_0), and at identical magnitudes of the pressure impulse I_K, the gas pressure in a conical bore exceeds that in a cylindrical bore because of an increase in the burnt part of the charge $\psi = \psi_0 + x$. And since the ballistic properties of the barrels must be compared at the identical maximum pressure p_m, it follows that, without altering the other loading conditions, it is possible to obtain identical pressures in both bores as a result of a change in the impulse I_K.

Let us determine the relation between the pressure impulses (or powder thicknesses) for a conical barrel with the calibers d_0 and d_D and for cylindrical barrels with the same calibers.

For cylindrical barrels of different calibers, at a given weight of the projectile and at given p_m and Δ, $B_0 = B_D$, from which:

$$s_0 I_{K0} = s_D \cdot I_{KD}.$$

The greater the caliber the smaller I_K.

$$\frac{I_{K0}}{I_{KD}} = \frac{s_D}{s_0} = y^2; \quad I_{KD} = I_{K0} \frac{s_0}{s_D} = \frac{I_{K0}}{y_D^2}.$$

To start with, we shall find the relation between I_K for the conical barrel and I_{K0} for the cylindrical barrel of caliber d_0. Let us determine how the quantities x and ψ vary as a function of v in the conical and cylindrical barrels if the caliber is d_0.

For Cylindrical Barrel

$$x' = \frac{\varphi m}{s_0 I_{K0}} v$$

For Conical Barrel

$$x = \frac{\varphi m}{s_0 I_X} \frac{v}{\frac{s_{av.}}{s_0}} > x'$$

In this connection, as v increases and $s_{av.}/s_0$ decreases, the difference x - x' grows uninterruptedly.

In fig. 177, x' and x are shown as functions of v. x' - v is the straight line o'bx'; x - v is the curve o'ax with the same tangent o'bx' at the start of motion of the projectile at v = 0.

GRAPHIC NOT REPRODUCIBLE

Fig. 177 - Diagram of Variation of x in Conical and Ordinary Bores.

For a given value of v_m' at identical values of Λ_m', $x_m > x_m'$, $\psi_m > \psi_m'$, $p_m > p_m'$. In order to obtain $p_m = p_m'$, it is necessary, by changing the pressure impulse, to lower the curve o'ax, equating the intensities of gas formation for the cylindrical and conical bores over the segment from 0 to v_m'.

Let us consider a powder with a constant burning area:

$$\psi = \psi_0 + x.$$

It is not difficult to see that the tangent of the angle of slope of the lines characterizes the intensity of gas formation. As a matter of fact:

$$\frac{dx}{dv} = \frac{d\psi}{dv} = \frac{d\psi}{dt}\frac{dt}{dv},$$

but:

$$\frac{dv}{dt} = \frac{sp}{\varphi m}.$$

Consequently:

$$\frac{dx}{dv} = \frac{\varphi m}{sp}\frac{d\psi}{dt} = \frac{\varphi m}{s}\Gamma,$$

where:

$$\Gamma = \frac{\varkappa}{I_K} \sigma .$$

For this reason, for a powder with a constant area of burning $\Gamma = 1/I_K$, $dx/dv = \varphi m/sI_K$; for a conical barrel, s decreases and dx/dv increases. We impose the requirement that the average value of dx/dv along the segment from zero to v'_m be equal to $\frac{dx'}{dv} = \frac{\varphi m}{s_0 I_{K0}}$ for the cylindrical barrel. Then:

$$\frac{\varphi m}{s_{av.}^{(m)} I_K} = \frac{\varphi m}{s_0 I_{K0}} \text{ and } I_K = I_{K0} \frac{s_0}{s_{av.}^{(m)}},$$

where $s_{av.}^{(m)}$ is the average value for the cross section of the conical bore from the start of motion to the attainment of v'_m, i.e., to the attainment of p_{max}. Since Λ'_m is known on the basis of the course of the $v' - \Lambda'$ curve for the cylindrical barrel, it is possible to determine:

$$\frac{s_{av.}^{(m)}}{s_0} \approx y^{(m)} = \sqrt[3]{1 - \frac{\Lambda_m}{\Lambda_{con.}}}.$$

Thus:

$$I_K = I_{K0} : y^{(m)} = I_{KD} \frac{s_D}{s_0} \frac{s_0}{s_{av.}^{(m)}}.$$

For $\Lambda_{con.}$ = about 6.0:

$$\Lambda'_m \approx 0.6, \ y^{(m)} = 0.97;$$

For $\frac{d_0}{d_D} = 1.4$:

$$\frac{s_0}{s_D} = 1.96;\ I_K = I_{K0}\frac{1}{0.97} \approx 1.03 I_{K0};\ I_K = 1.03\frac{1}{1.96} I_{K0} = 0.527 I_{KD};$$

For $\Lambda_{con.} = 10$:

$$y_m = 0.983.$$

Consequently, in order to obtain an identical maximum pressure p_m, the thickness of the powder in the conical barrel ($d_0/d_D = 1.4$) must be a little greater (by 3%) than the thickness of the powder for the cylindrical barrel of caliber d_0, which is equal to the entrance caliber of the conical bore.

It must be considerably thinner (by nearly 50%) than the thickness of the powder for the cylindrical barrel of caliber d_D (at the same W_0, Δ, and ω/q):

$$I_{K0} < I_K \ll I_{KD}.$$

For this reason, it is erroneous to compare, as is sometimes done, a conical barrel and a cylindrical barrel of caliber d_D with the same powder thickness selected for this cylindrical barrel; in this case, the maximum pressure in the conical barrel will be obtained several times lower than in the cylindrical barrel, and the powder will not even burn to the end.

3. RELATION OF LENGTHS OF BARRELS WITH CONICAL AND CYLINDRICAL BORES.

Since the projectile is ejected from the conical bore while having a caliber d_D at a normal c_{qD}, which ensures its attaining the predetermined range and speed of encounter with an obstacle, the ballistic

characteristics of the conical barrel should be compared with those for a cylindrical barrel having a caliber d_D, which is equal to the exit caliber of the conical bore.

At the same W_0, Δ, ω/q, p_m, and v_D, the working volumes of the bores W_D will also be equal.

Let us determine the relation between the lengths of the path l_D in the conical bore and $l_D^{(D)}$ in the cylindrical bore of caliber d_D.

From the condition of equality of working volumes W_D, we have:

$$W_D = s_D l_D^{(D)} = s_0 \frac{1 + y_D + y_D^2}{3} l_D$$

or:

$$l_D = l_D^{(D)} \frac{s_D}{s_0} \frac{3}{1 + y_D + y_D^2} = l_D^{(D)} \frac{3y_D^2}{1 + y_D + y_D^2}.$$

The relative diminution in the length of the conical bore is:

$$\frac{\delta l_D}{l_D^{(D)}} = \frac{l_D^{(D)} - l_D}{l_D^{(D)}} = \frac{1 + y_D - 2y_D^2}{1 + y_D + y_D^2}.$$

At the ratio $\frac{d_0}{d_D} = \frac{28}{20} = 1.4$:

$$y_D = 0.715;\ y_D^2 = 0.511;$$

$$\frac{\delta l_D}{l_D^{(D)}} = \frac{1.715 - 1.022}{1.715 + 0.511} = 0.311, \text{ or } 31.1\%.$$

At $\frac{d_0}{d_D} = \frac{75}{55} = 1.362$:

$$y_D = 0.734; \; y_D^2 = 0.539;$$

$$\frac{\delta l_D}{l_D^{(D)}} = \frac{1.734 - 1.078}{1.734 + 0.539} = \frac{0.656}{2.273} = 0.2885, \text{ or } 28.9\%.$$

With respect to the length of the conical barrel, the difference in length will give the following lengthening:

$$\frac{\delta l_D}{l_D^{(K)}} = \frac{l_D^{(D)} - l_D}{l_D^{(K)}} = \frac{l_D^{(D)}}{l_D^{(K)}} - 1 = \frac{1 + y_D - 2y_D^2}{3y_D^2}.$$

For 28/20:

$$\frac{\delta l_D}{l_D} = \frac{0.693}{3 \cdot 0.511} = 0.452, \text{ or } 45.2\%;$$

for 75/55:

$$\frac{\delta l_D}{l_D} = \frac{0.656}{3 \cdot 0.539} = 0.405, \text{ or } 40.5\%$$

Conclusion. At the same chamber and bore volumes W_0, W_D, and W_{KH}, and under the same loading conditions (q, ω, Δ, ω/q), a conical barrel d_0/d_D as compared with a cylindrical barrel of a caliber d_D equal to the exit caliber of the conical barrel, must give at existing ratios $d_0/d_D = 1.4$ the same initial velocity v_D and the same maximum pressure with a length of path of the projectile reduced by about 30% and with a powder

thickness reduced in the following ratio:

$$\left(\frac{d_D}{d_0}\right)^2 = \frac{s_D}{s_0}.$$

<u>The reduction in length constitutes the principal advantage of a conical barrel in comparison with a cylindrical barrel at equal exit calibers</u>. This advantage possesses particular importance at high initial velocities of the projectile, when an excessively great length (about 150 d) is obtained for the cylindrical barrel, which makes the gun inconvenient for combat use and for transport. Moreover, great length combined with a small diameter results in sagging of the barrel and vibration during firing.

4. CONSIDERATION OF SECONDARY WORK IN CONICAL BORE.

The comparison between the ballistic characteristics of the conical and cylindrical bores presented above was conducted on the assumption that the coefficient φ, which takes into account the secondary work, is identical in the two cases. As a matter of actual fact, the gun with a conical bore has a number of features which reflect themselves in the magnitude and character of the secondary work.

The principal features include the following:

(a) The motion of the charge gases and of the as yet unburnt part of the charge takes place in a bore with a cross section which continuously decreases in the direction of motion of the projectile.

(b) There occurs a continuous deformation of the rotating bands of the projectile, which causes an equally continuous increase in the resistance forces until the projectile passes through the minimum cross

section of the bore.

For the coefficient of secondary work φ, we shall adopt the following general expression: $\varphi = a_K + b_K \frac{\omega}{q}$. The first feature must be reflected in the coefficient b_K, which may be of considerable importance at high projectile velocities and at large $\frac{\omega}{q}$, at which, in fact, it is alone advantageous to employ conical barrels.

The second feature must be reflected in the magnitude of the term a_K, which takes into account the resistance forces developed during the deformation of the bands, these forces increasing continuously and retarding the motion of the projectile in considerably greater measure than is the case in a cylindrical bore. Simultaneously with this, there occurs an increase in the part of the work expended in the conical barrel to overcome friction over the ever-increasing area of contact between the bands of the projectile and the bore.

While in small-arms, where the entire lateral surface of the bullet cuts itself into the rifling grooves, a = 1.10 instead of 1.03 for artillery guns, a_K in the conical barrel must be still greater.

For a cylindrical barrel without chamber widening:

$$b = \frac{1}{3}.$$

For a cylindrical barrel with a chamber widening $\chi = l_0 / l_{KM}$:

$$b = \frac{1}{3} \frac{\Lambda + \frac{1}{\chi}}{\Lambda + 1},$$

where $\Lambda = \frac{l}{l_0}$ is the current value of the volumetric expansion ratio. As the projectile moves, b varies from $b_0 = \frac{1}{3}\frac{1}{\chi}$ at the start of the

motion at $\Lambda = 0$ to $b_D = \frac{1}{3}\frac{\Lambda_D + \frac{1}{\chi}}{\Lambda_D + 1}$, where $b_D > b > b_0$, and approaches 1, 3 as Λ_D increases.

In deriving the formula for b_K with consideration of chamber widening, the following assumptions have been made, which extend to the motion of the gases in the bore of the conical barrel.

The gas velocity in various cross sections varies in accordance with a linear law from the chamber bottom to the bottom of the projectile; the mass of the gases is uniformly distributed in the space, but what takes part in the motion is not the entire gas mass but only that which has a cross section s equal to the current cross section of the conical bore or to the cross section of the cylindrical bore. The internal friction of the gases and their friction against the walls of the bore are neglected.

Let the chamber of the conical bore have a widening characterized by the quantity $\chi = l_0/l_{KM}$, and let the conical bore itself be characterized by the ratio of diameters $d_D/d_0 = y_D$ for the muzzle face and $d/d_0 = y$ for the current position of the projectile after the latter has traversed the path l.

The relative weight ω_{DB} of the gases taking part in the motion (upon the displacement of which the work $b_K \frac{\omega}{q}$ is expended), stated as a fraction of the total weight of the charge ω, is expressed by the following formula:

$$\frac{\omega_{DB}}{\omega} = \frac{s(l_{KM} + l)}{W_0 + W} = \frac{\frac{s l_{KM}}{s_0 l_0} + \frac{s_{av.}}{s_0}\frac{l}{l_0}\frac{s}{s_{av.}}}{1 + \Lambda} = \frac{\frac{s}{s_0}\frac{1}{\chi} + \frac{s}{s_{av.}}\frac{W}{W_0}}{1 + \Lambda} .$$

$$= \frac{\frac{s}{s_0}\left(\frac{1}{\chi} + \frac{s_0}{s_{av.}}\Lambda\right)}{1 + \Lambda},$$

where $\Lambda = W/W_0$. Since:

$$\frac{s}{s_0} = y^2; \quad \frac{s_{av.}}{s_0} = \frac{1 + y + y^2}{3} \approx y,$$

it follows that:

$$\omega_{DB} = \omega y^2 \frac{\frac{1}{\chi} + \frac{\Lambda}{y}}{1 + \Lambda} = \omega y \frac{\Lambda + \frac{y}{\chi}}{\Lambda + 1}.$$

The work expended upon the displacement of the cylindrical column of gas with the cross section s and weight ω_{DB} is represented in the over-all balance by the component:

$$\frac{1}{3}\frac{\omega_{DB}}{q} = \frac{1}{3}\frac{\omega}{q}\frac{\omega_{DB}}{\omega}.$$

Replacement of ω_{DB} by the expression for it gives:

$$b_K = \frac{1}{3} y \frac{\Lambda + \frac{y}{\chi}}{\Lambda + 1}.$$

For the cylindrical bore, y = 1, and we obtain the previously derived formula:

$$b = \frac{1}{3}\frac{\Lambda + \frac{1}{\chi}}{\Lambda + 1};$$

Since for the conical bore $y < 1$, it follows that $b_K < b$.

Thus, the work expended upon the displacement of the parts of the charge is smaller in a conical bore than in a cylindrical bore under conditions of identical values for χ, ω and Λ, the difference between the two continuously increasing as the projectile moves forward (since, as Λ increases, y in the expression for b_K decreases).

Examination of the expression for b_K shows that, at $\chi = 1$, $\Lambda = 0$, $y = 1$, $b_{K0} = 1/3$, and that, as Λ increases and y decreases, the quantity b_K decreases.

At $\chi > 1$, the quantity b_{K0} starts out with $b_{K0} = \frac{1}{3}\frac{1}{\chi}$, then, as Λ increases, it grows at first, passes through a maximum, and thereupon continusously decreases.

In this connection, the maximum b_K is obtained the later the larger χ, and the decrease in b_K proceeds the more rapidly the greater the conicity and the smaller $\Lambda_{con.} = W_{con.}/W_0$. There is presented below a table of values for the coefficients b_K and $b_{K_{av.}}$ in a conical barrel at $\Lambda_{con.} = 6.0$ and $\chi = 1.8$.

$\chi = 1.8$; $\Lambda_{con.} = 6.0$

Λ	0	0.2	0.4	0.6	0.8	1	2	3	4
b_K	0.185	0.205	0.219	0.228	0.235	0.238	0.241	0.227	0.203
$b_{K_{av.}}$	0.185	0.195	0.203	0.210	0.216	0.220	0.231	0.232	0.230

Diagrams of curves for $b_{K_{av.}}$ and $b_{av.}$ at various χ for conical and cylindrical bores are presented in fig. 178.

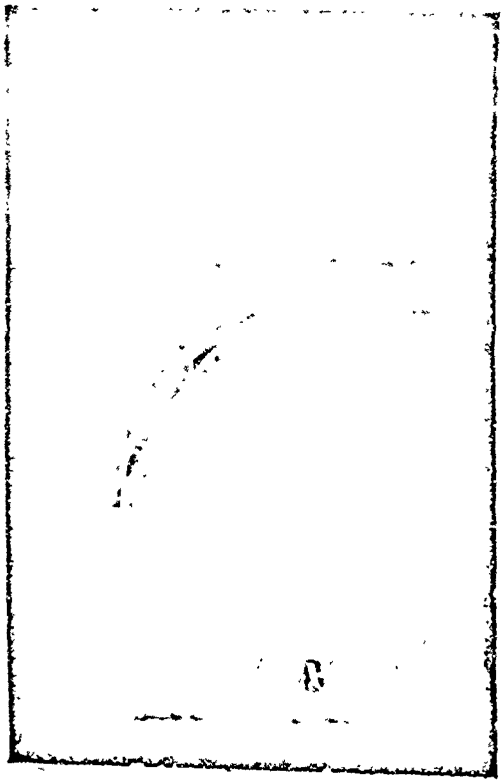

Fig. 178 - Variation of Coefficient b in Conical and Cylindrical Bores.

The guidance of a projectile with two skirt bands through a conical bore differs considerably from the guidance of an ordinary projectile with a copper rotating band through a cylindrical bore. In the latter, the resistance increases sharply as the band cuts itself into the rifling grooves. After the band has cut itself in to the full depth of the rifling grooves, the resistance drops sharply, and thereupon, to overcome the friction in the rifling grooves, there is consumed about 1% of the energy expended to communicate a forward motion to the projectile (k_3 = about 0.01). In this connection, the friction due to the radial force Φ is usually neglected.

During the motion of a projectile with two guiding bands through a conical bore, the cutting of the bands into the rifling grooves and the compression of progressively thicker parts of the bands must increase

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diameter d_0' is somewhat greater than the land diameter of the gun (d_0' = about 28.3, d_0 = 28.0). The diameter of the body of the projectile, d_1 = about 19 mm, is smaller than d_D = 20 mm, in order to give a clearance for the compression of the forward band:

$$b_0 = 3 \text{ mm}; \; b_1 \approx 9 \text{ mm}.$$

The angle of inclination of the generatrix of the cone ecb with respect to the axis of the projectile is α = about 30°. At the start of the motion, the projectile, while pressing apart the rolled-up part of the cartridge with its forward band, moves through the 35-mm long smooth cylindrical part of the bore, and only then cuts itself into the rifled conical part. The gases act upon the inner cavity of the rear band and press it toward the surface of the bore along the cylindrical part ab, whose surface at the start of the motion is:

$$S_{n0} = \pi d_0' b_0.$$

As they cut themselves into the conical part of the bore, both bands are compressed and elongated toward the rear. After ejection of the projectile, the rear band has the appearance represented in fig. 180; its outer surface shows traces of the rifling grooves.

Fig. 180 - Rear Band after Compression.

The deformation of the outer surface of the rear band and the law governing the change in the surface of contact can be determined with the aid of the simplified scheme represented in figs. 181 and 182.

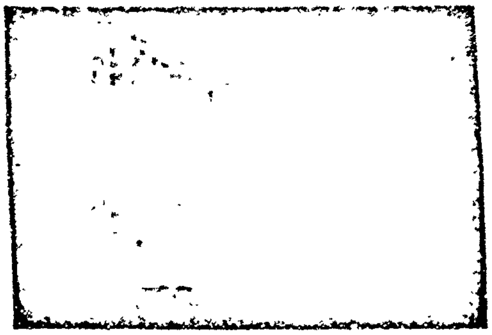

Fig. 181 - Scheme of Compression of Rear Band.

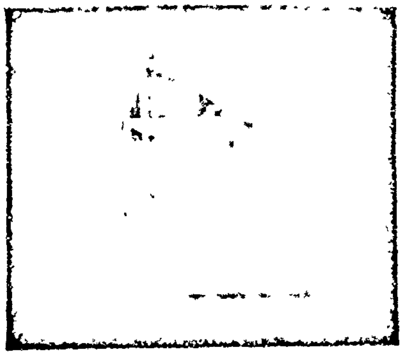

Fig. 182 - Scheme of Deformation of Rear Band.

The fundamental assumption made as a result of measuring the bands before and after the shot is that the length of the generatrix of the band always remains the same, i.e.:

$$l_{\text{п}} = ecba = ecb'a'.$$

The deformation of the surface of contact consists in the transformation of the initial cylindrical surface of diameter d_0' into a cylindrical surface of diameter d. The slight conicity is neglected, and the surface of contact is considered to be cylindrical:

$$S_{\text{п}} = \pi d(a'b' + b'c).$$

But:

$$b'c = bc = \frac{d_0' - d}{2 \sin \alpha} \approx \frac{d_0 - d}{2 \sin \alpha},$$

since the difference between the diameters d_0 and d_0' does not exceed 1%.

Making use of the previously derived designation $y = d/d_0$, and taking into account that $s_0 = \frac{\pi}{4} d_0^2$, we have:

$$S_n = \pi d_0 y \left(b_0 + \frac{d_0 - d}{2 \sin \alpha} \right) = \frac{\pi d_0^2}{4} y \left[\frac{4b_0}{d_0} + \frac{2(1 - y)}{\sin \alpha} \right] =$$

$$= s_0 y^2 \left[\left(\frac{4b_0}{d_0} + \frac{2}{\sin \alpha} \right) \frac{1}{y} - \frac{2}{\sin \alpha} \right] =$$

$$= s \left[\left(\frac{4b_0}{d_0} + \frac{2}{\sin \alpha} \right) \frac{1}{y} - \frac{2}{\sin \alpha} \right],$$

where $s = s_0 y^2$ is the current value for the cross section of the conical bore.

Consequently, the bracketed expression represents the ratio of the surface of the band pressed against the surface of the conical bore to the cross section of this bore. Since y diminishes all the time, S_n / s continuously increases.

As the projectile moves through the conical bore, there will be developed the following frictional force:

$$R_T = \xi \nu_1 S_n p_{CH},$$

where $\xi < 1$, since, as a result of the rigidity of the metal, the pressure p is incompletely transmitted to the frictional surface. Moreover, the pressure p acts upon a surface which is smaller than S_n, especially at the end of compression of the band (cf. scheme in fig. 182, where the pressure is not transmitted to the segment ec').

The work required to overcome this force is:

$$\int_0^l R_T dl = \xi \nu_1 \int_0^l S_{\text{П}} p_{CH} dl.$$

Replacing $S_{\text{П}}$ in accordance with the formula presented above, we obtain:

$$\int_0^l R_T dl = \xi \nu_1 \int_0^l \left[\left(4 \frac{b_0}{d_0} + \frac{2}{\sin\alpha} \right) \frac{1}{y} - \frac{2}{\sin\alpha} \right] p_{CH} \cdot s dl \; ;$$

but $s dl = dW$, and $\int p_{CH} dW =$ about $\frac{mv^2}{2}$.

Upon taking the bracketed expression outside the integral sign in the form of an average value, we obtain:

$$\int_0^l R_T dl = \xi \nu_1 \left[\left(4 \frac{b_0}{d_0} + \frac{2}{\sin\alpha} \right) \left(\frac{1}{y} \right)_{av.} - \frac{2}{\sin\alpha} \right] \frac{mv^2}{2}.$$

Consequently, the relative work expended to overcome friction is:

$$k_3'' = \xi \nu_1 \left[\left(4 \frac{b_0}{d_0} + \frac{2}{\sin\alpha} \right) \left(\frac{1}{y} \right)_{av.} - \frac{2}{\sin\alpha} \right].$$

Since $y = \sqrt[3]{1 - \frac{\Lambda}{\Lambda_{con.}}}$, it follows that:

$$\frac{1}{y_{av.}} = \frac{1}{\Lambda/\Lambda_{con.}} \int_0^{\frac{\Lambda}{\Lambda_{con.}}} \left(1 - \frac{\Lambda}{\Lambda_{con.}} \right)^{-\frac{1}{3}} d \frac{\Lambda}{\Lambda_{con.}}.$$

Upon introducing a new variable $t = 1 - \frac{\Lambda}{\Lambda_{con.}}$, we obtain after certain transformations:

$$\left(\frac{1}{y}\right)_{av.} = \frac{3}{2}\frac{1 - y^2}{\Lambda/\Lambda_{con.}}.$$

At $b_0/d_0 = 0.1$, $\alpha = 30^\circ$, $\xi = 1$, $\nu_1 = 0.10$, we obtain the following table of values of $(1/y)_{av.}$ and k''_3 (Table 5).

Table 5

$\frac{\Lambda}{\Lambda_{con.}}$	0	0.10	0.20	0.30	0.40	0.50	0.60	0.70
$\left(\frac{1}{y}\right)_{av.}$	1	1.017	1.037	1.059	1.082	1.110	1.143	1.183
k''_3	0.040	0.9445	0.0563	0.0658	0.0762	0.0884	0.1028	0.1204

The numbers presented in the table show that the coefficient k''_3, in varying from 0.04 to 0.12, considerably exceeds in value the coefficient k_3 in the cylindrical barrel (k_3 = about 0.01).

But, in the expression for k''_3, no account is taken of the work expended upon the deformation of the bands and upon overcoming the resisting forces developing on the surface of contact between the bands and the bore.

To obtain more accurate data on the forces and energies expended during the drawing of a projectile through a conical bore, there were conducted in 1943-1945 tests on pressing projectiles for the 28/20 gun through dies of various conicities, the purpose being subsequently to compute the forces and energies required to press similar projectiles

through the barrel of the 28/20 gun.

In order to segregate the influence of each band, the forward band was reduced in diameter (on a lathe) on one set of projectiles, so that only the rear band remained in operation, while the rear band was reduced on another set of projectiles, so that only the forward band remained in operation; a third set of projectiles was pressed through with both bands intact.

The dies, 28 mm and 20 mm in diameter, differed in length and in their angles of conicity β ($\tan\beta = 0.040$, 0.025, and 0.020).

The pressing through the dies was performed statically in an Amsler press with the aid of a rod which transmitted the pressure from the press to the bottom of the projectile.

The tests revealed the following relations:

1) In the presence of only one band - either the forward or the rear band - the force diagrams have the appearance represented in fig. 183, where (1) is the projectile with the forward band and (2) is the projectile with the rear band:

$$\Pi_{max\ 2} \approx 2\Pi_{max\ 1}.$$

Since the rear band is considerably thicker and more massive than the forward band, its entire force curve lies higher than the curve for the forward band.

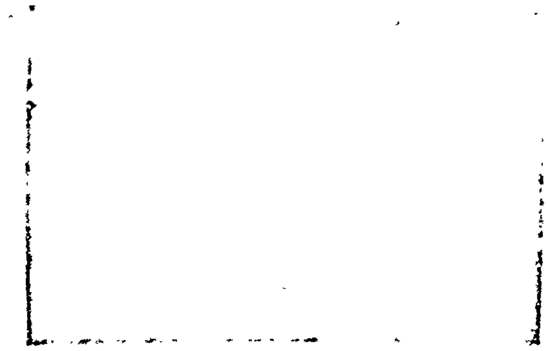

Fig. 183 - Scheme of Forces in Compressing Individual Bands.

Ordinate: Π, kg.

2) In the presence of both bands, one of which is displaced with respect to the other by a certain distance, the force diagram has the appearance represented in fig. 184.

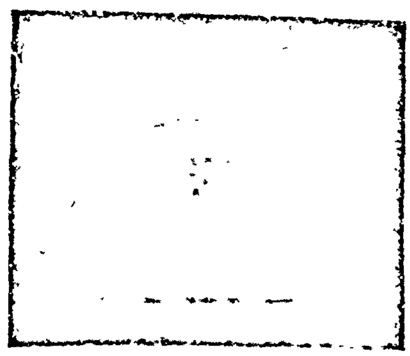

Fig. 184 - Summation of Forces in Compressing Both Bands.

The initial segment of the curve corresponds to the compression of only the forward band (while the rear band is still moving through the cylindrical part of the die); at the point a, the force Π_2 begins to be added to the force Π_1, and the Π_{1+2} curve is obtained by adding together the ordinates of the curves for Π_1 and Π_2, which are shifted with respect to each other by the distance a_1 between the bands.

The results of the pressing tests are summarized in Table 6.

Table [illegible]

Die no.	tan β	Length of conical part, mm	Π_{max} for both bands	$\Pi_{max\ 2}$ for rear band	$\Pi_{max\ 1}$ for forward band	A_2, kg·dm
			kg			
1	0.040	100	3500	2620	1350	1480/100
2	0.025	160	3250	2350	1180	1980/133
3	0.020	200	3100	2250	1100	2520/170

In all three cases, the conicity exerts a slight effect upon the magnitude of Π_{max}; as the conicity changes by a factor of two (from the first to the third case), Π_{max} changes by only 400 kg for both bands (equivalent to 11.5%) and by only 250 kg for the forward band (equivalent to 12.3%).

3) The area of the $\int_0^{l_K} \Pi dl$ diagram, where l_K is the length of the conical segment of the die, defines the magnitude of the work expended upon pressing the projectile through the die (fig. 185).

Fig. 185 - Forces as Functions of Angle of Slope of Cone.

The work is substantially dependent upon the path traversed by the projectile. It is least in the shortest die, so that:

$$\int_0^{l_M^{(1)}} \Pi \, dl < \int_0^{l_M^{(2)}} \Pi \, dl < \int_0^{l_M^{(3)}} \Pi \, dl .$$

To take into account the work necessary to press the projectile through the conical bore of the gun itself, the force diagram for the die, $\Pi_M = f_M(l)$, must be transformed into a force diagram applicable to the operation of pressing through the barrel, $\Pi_c = f_c(l)$.

5. DERIVATION OF FORMULA FOR RECOMPUTATION OF PRESSING FORCES FROM DIE TO BARREL (*)

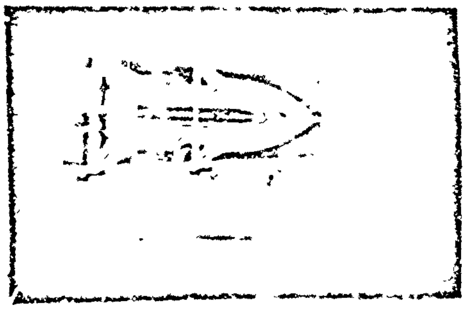

Fig. 186 - Scheme of Forces During Passage of Projectile.

As the projectile is pressed through a die or a barrel, it is acted upon by the following forces (Fig. 186):

1) The force of the press Π, which is directed along the axis of the projectile.

2) The reaction force N' perpendicular to the conical surface, which is uniformly distributed over the variable surface of contact of the forward band.

3) The analogous force N'' on the rear band.

4) The frictional force $\nu_1 N'$ on the forward band.

(*) Derivation performed by Engineer Shpigelburd.

5) The frictional force $\nu_1 N''$ on the rear band.

Upon resolving the reaction forces N and νN into their components parallel and perpendicular to the axis of the bore and of the projectile, we find that the projectile is acted upon in the axial direction by the following three forces:

$$\Pi, \quad (N' + N'')\sin\beta, \quad (N' + N'')\nu_1 \cos\beta;$$

and that the following two forces act in the radial direction:

$$(N' + N'')\cos\beta, \quad (N' + N'')\nu_1 \sin\beta.$$

For the static pressing of the projectile through the die, the equilibrium conditions for the forces in the axial direction will give the following equation (designating $N' + N'' = N$):

$$\Pi = N(\sin\beta + \nu_1 \cos\beta). \qquad (53)$$

The radial forces compressing each band:

$$\Phi' = N'(\cos\beta - \nu_1 \sin\beta) \text{ and } \Phi'' = N''(\cos\beta - \nu_1 \sin\beta)$$

cause the bands to undergo plastic deformation.

In transferring the pressing-force diagram from the die to the barrel, we make the assumption that identical radial forces act in similar cross sections of the die and of the barrel which correspond to one and the same diameter.

In such a case, for similar cross sections of the barrel and of the die, we can write the following equation of radial forces (the subscript "M" indicating the die, and the subscript "c" indicating the barrel):

$$N_M(\cos\beta_M - \nu_{1M}\sin\beta_M) = N_c(\cos\beta_c - \nu_{1c}\sin\beta_c). \qquad (54)$$

On the basis of formula (53), we have:

$$\Pi_M = N_M(\sin\beta_M + \nu_M\cos\beta_M);\ \Pi_c = N_c(\sin\beta_c + \nu_c\cos\beta_c),$$

from which:

$$\frac{\Pi_c}{\Pi_M} = \frac{N_c}{N_M}\,\frac{\sin\beta_c + \nu_c\cos\beta_c}{\sin\beta_M + \nu_M\cos\beta_M}.$$

Upon replacing the ratio N_c/N_M as indicated in expression (54), we obtain:

$$\Pi_c = \Pi_M\,\frac{\cos\beta_M - \nu_M\sin\beta_M}{\cos\beta_c - \nu_c\sin\beta_c}\,\frac{\sin\beta_c + \nu_c\cos\beta_c}{\sin\beta_M + \nu_M\cos\beta_M} =$$

$$= \Pi_M\,\frac{\tan\beta_M}{\tan\beta_c}\,\frac{\cot\beta_M - \nu_M}{\cot\beta_c - \nu_c}\,\frac{\tan\beta_c + \nu_c}{\tan\beta_M + \nu_M}. \qquad (55)$$

Since:

$$\cot\beta_M \gg \nu_M \text{ and } \cot\beta_c \gg \nu_c,$$

then, assuming:

$$\frac{\tan\beta}{\tan\beta_c}\,\frac{\cot\beta_M - \nu_M}{\cot\beta_c - \nu_c} = 1,$$

We can reduce formula (55) to the following simpler form:

$$\Pi_c = \Pi_M\,\frac{\tan\beta_c + \nu_c}{\tan\beta_M + \nu_M}. \qquad (56)$$

Applying formula (56) to two dies of different conicities, assuming ν_M to be the same, and knowing Π_1 and Π_2 from the pressing diagram obtained with the aid of the press, there was obtained $\nu_M = 0.16$, which corresponds to the data accepted in technology. This demonstrates the correctness of the initial assumptions.

Formula (56) serves for recomputation of the forces required to press the projectile through the barrel.

Since the bore of the 28/20 gun consists of segments of different conicities, it follows that, in those places where the conicity changes, the rear band of the projectile will be on one segment, and its forward band will be on the other. For this reason, it is necessary to use formula (56) in such a manner as to transform from the die to the barrel the $\Pi - l$ diagrams for each band separately, whereupon the diagrams are added together.

During rapid motion of the projectile through the bore, the coefficient of friction decreases in conformity with the following formula:

$$\nu = \nu_0 \frac{1 + a_1 v}{1 + a_2 v},$$

where $a_1 < a_2$.

In accordance with the data of M.M. Shlyaposhnikov, $\nu_0 = 0.27$, $a_1 = 0.0213$, $a_2 = 0.133$. In accordance with the data of Robinson [3], ν is close to 0.05 at $v > 200$ m/sec.

Assuming ν_c to have an average value (0.1 or less), we can use formula (56) to obtain the forces involved in pressing the projectile through the barrel.

For the 28/20 gun, which comprises three segments of different conicities, there is obtained at $\nu_{av.} = 0.10$ the $\Pi = f(l)$ force

diagram represented in fig. 187.

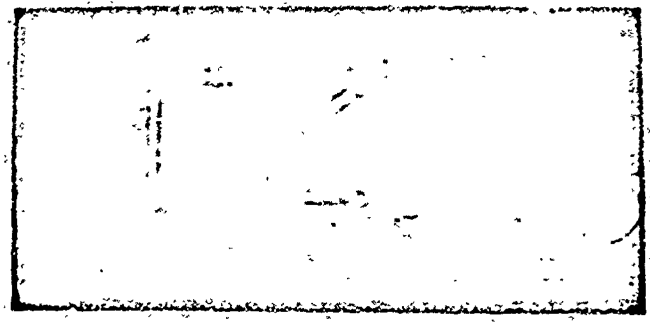

Fig. 187 - Resistance to Drawing through 28/20 Barrel.

1) cylindrical bore; 2) conical bore of 28/20 antitank gun; 3) profile of 28/20 antitank gun bore.

Computation of the work involved in static pressing through the bore at $\nu_c = 0.10$ gave the value of $A = 1320$ kg·m, which constitutes about 10% of the muzzle energy of the projectile. At existing conicities, $\int \Pi dl$ depends in considerably greater measure upon the coefficient of friction ν than upon $\tan \beta$.

As is seen from the results of the computation, this value is considerably greater than the work required to overcome friction in a cylindrical barrel, where k_3 = about 0.01, or approximately 1%.

The coefficient φ_K for the conical barrel can thus be represented in the following form:

$$\varphi_K = a_K + b_K \frac{\omega}{q},$$

where:

$$a_K = 1 + k_2 + k_3' + k_3'' + k_3^{(K)} + k_5.$$

Here, k_2 is the relative work consumed in rotating the projectile, k_2 is about 0.01;

k_3' is the relative work consumed in overcoming friction on the driving edges of the two bands, k_3' = about 0.02;

$k_3^{(K)}$ is the relative work consumed in overcoming the resistance forces due to the friction of the bands against the surface of the bore and by the deformation

of the bands, $k_3^{(K)} = \frac{\int_0^l \Pi dl}{\frac{mv^2}{2}}$, $k_3^{(K)} \approx 0.10$;

k_3'' is the relative work consumed in overcoming the additional friction caused by the pressing of the rear band against the surface of the bore under the action of the gas pressure, k_3'' = 0.04-0.08;

k_5 is the relative work consumed by the recoil, $\frac{k_5 \approx 0.01}{\Sigma k_i = 0.18-0.22}$.

Thus:

$$a_{K_{av.}} = 1.20; \; b_K = \frac{1}{3} y \frac{\Lambda + \frac{Y}{\chi}}{\Lambda + 1} \approx 0.22.$$

For Cylindrical Bore: **For Conical Bore:**

For charge $\frac{\omega}{q} = 1$

$$\varphi = 1.03 + \frac{1}{3}\frac{\omega}{q} = 1.363. \qquad \varphi_K = 1.20 + 0.222\frac{\omega}{q} = 1.422;$$

For charge $\frac{\omega}{q} = 1.5$

$$\varphi = 1.03 + \frac{1}{3}\frac{3}{2} = 1.53. \qquad \varphi_K = 1.20 + 0.333 = 1.533;$$

For charge $\frac{\omega}{q} = 2.0$

$$\varphi = 1.03 + \frac{2}{3} = 1.70, \qquad \varphi_K = 1.20 + 0.444 = 1.644.$$

Consequently, for the charge $\omega/q = 1.5$ (which corresponds to $v_D =$ = about 1500 m/sec), the identical coefficients φ and φ_K are obtained for the cylindrical and conical bores, even though the components a and $b\frac{\omega}{q}$ differ:

$$a_K > a, \; b_K < b.$$

At smaller relative charges ω/q, the coefficient φ_K for the conical barrel is greater than φ for the cylindrical barrel. At $\frac{\omega}{q} > 1.5$, at projectile velocities $v_D > 1500$ m/sec, $\varphi_K < \varphi$, and the conical bore is found to be more advantageous, since, at a large relative charge, the decrease in the coefficient $b_K\frac{\omega}{q}$ is more pronounced.

At very high initial projectile velocities, higher than 1500 m/sec, the barrel with the conical bore is more advantageous not only because it considerably reduces the length of the bore, but also because it reduces the quantity of work consumed in moving the gases in the narrowing bore $\left(\text{term } b_K\frac{\omega}{q}\right)$.

If the values for the coefficients k_3'' and $k_3^{(K)}$ are not averaged and the problem is solved for variable magnitudes of the resistance forces, the following system of equations is obtained:

1) Equation of motion:

$$sp_{CH} - \xi\nu_1 S_n p_{CH} - \Pi = \varphi_1 m \frac{dv}{dt}. \qquad \text{(a)}$$

2) Equation of work or equation of transformation of energy:

$$p(W_\psi + W) = f\omega\psi - \frac{\theta}{2}\varphi_2 mv^2 - \theta \int_0^l \Pi dl - \xi \int_0^l \nu_1 S_\Pi p dl. \qquad \text{(b)}$$

3) Law of burning rate:

$$u = u_1 p. \qquad \text{(c)}$$

4) Law of gas formation:

$$\psi = \varkappa z + \varkappa\lambda z^2. \qquad \text{(d)}$$

5) Relation between p_{CH} and p (average):

$$p = p_{CH}\left[1 + \frac{1}{3}\frac{y}{\varphi_1}\frac{\Lambda + \frac{y}{\chi}}{\Lambda + 1}\right]. \qquad \text{(e)}$$

The coefficient φ_1 takes into account the work of the resistance forces on the driving edges of the rifling grooves and the work consumed in rotating the projectile. It is possible to assume that $\varphi_1 =$ = about 1.02. The coefficient φ_2 takes into account all the usual forms of work, except for the work accounted for separately by the last two terms in equation (b):

$$\varphi_2 = 1 + k_2 + k_3' + k_4 + k_5 \approx 1.03 + b_K \frac{\omega}{q},$$

where:

$$b_K = \frac{1}{3} y \frac{\Lambda + \frac{y}{\chi}}{\Lambda + 1}, \; y = \frac{d}{a_e}, \; \chi = \frac{l_0}{l_{KM}}.$$

The system represented by these equations is solved by the method of resolution into a Taylor's series, accompanied by the use of a series of diagrams expressing the dependence of Π, $\int \Pi dl$, S_{Π}, b_K and φ_2 upon K or Λ and the relation between ν_1 and the velocity of the projectile.

For verifying the correctness of the relations derived above by taking into account the various forms of secondary work, it is expedient to utilize the above system of equations (a-e) at very small charges, using a very rapid-burning powder.

In this case, which is close to the case of instantaneous burning of the powder, equations (c) and (d) are eliminated, the coefficient φ_2 is close to being constant because of the smallness of ω/q, and the retarding forces $R = \xi \nu_1 S_{\Pi} p_{CH}$ and Π acquire predominant importance and can more easily be taken into account.

If equation (a) is written in the following form:

$$sp_{CH}\left[1 - \xi\nu_1 \frac{S_{\Pi}}{s} - \frac{\Pi}{sp_{CH}}\right] = \varphi_1 m \frac{dv}{dt},$$

it becomes possible to select values of Δ and p_{CH} at which the bracketed expression will be very small, and may in a certain instant even become less than zero; the projectile will be retarded to such an extent that it will stop without emerging from the bore.

CHAPTER 2 - METHOD OF SOLUTION OF PROBLEM OF INTERIOR BALLISTICS

The fundamental assumptions are the same as in solving the problem for the usual cylindrical barrel: instantaneous ignition, geometric law of burning of the powder, law of rate of burning $u = u_1 p$, instantaneous cutting of the band into the rifling grooves at the pressure p_0 to overcome the inertia of the projectile; unchanging gas composition during expansion.

The fundamental distinction is the variable cross section of the bore.

Fundamental Relations

Equation of motion:

$$\varphi m \frac{dv}{dt} = sp \qquad (57)$$

Law of rate of burning:

$$u = \frac{de}{dt} = u_1 p \qquad (58)$$

Equation of elementary work:

$$\varphi m v\,dv = ps\,dl = p\,dW \qquad (59)$$

Equation of transformation of energy:

$$p(W_\psi + W) = f\omega\psi - \frac{\theta}{2}\varphi m v^2$$

where:

$$W_\psi = W_0\left[1 - \frac{\Delta}{\delta} - \Delta\left(\alpha - \frac{1}{\delta}\right)\psi\right] \qquad (60)$$

is the free volume of the chamber in the instant when the fraction of the charge ψ has burned.*)

From (57) and (58), we have, as usual: $s\,de = u_1 \varphi m\,dv$, or:

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*) $\varphi = a_K + b_K \frac{\omega}{q}$ in accordance with the formulas in the preceding chapter.

$$dv = \frac{s}{\varphi m}\frac{e_1}{u_1}dz = \frac{sI_K}{\varphi m}dx,$$

where:

$$x = z - z_0 = \frac{e}{e_1} - \frac{e_0}{e_1};$$

x is the relative thickness of the powder burnt since the start of motion of the projectile; e_0 is the thickness of the powder burnt in the instant of the start of motion; z_0 is the relative powder thickness; and ψ_0 is the fraction of the charge burnt prior to the same instant of time.

We introduce into equation (61) the relative quantity $\frac{s}{s_0}$:

$$dv = \frac{s_0 I_K}{\varphi m}\;\frac{s}{s_0}dx. \qquad (62)$$

The fundamental difficulty in solving the system of equations for the conical barrel consists in the fact that the connection between $\frac{s}{s_0}$ and v or x is not known in advance; it will be established later.

This makes it impossible to integrate equation (61).

We propose taking this connection from the solution of the problem for the cylindrical barrel, where we obtain a connection between v and W or:

$$\Lambda = \frac{W}{W_0}$$

From the fundamental assumption that, under identical loading conditions for the conical and cylindrical barrels, the v-Λ curves for both coincide, we obtain the relation between $\frac{s}{s_0}$ and W or Λ. Since the quantity Λ will subsequently be the argument, the ratio $\frac{s}{s_0}$ will be known in accordance with it, and the equation can be

integrated.

By integrating it, we obtain:

$$v = \frac{s_0 I_K}{\varphi m} \int_0^x \frac{s}{s_0} dx.$$

Taking $\frac{s}{s_0}$ outside the integral sign in the form of the average value of $\frac{s_{av.}}{s_0}$ from 1 to $\frac{s}{s_0}$, corresponding to the relative volume Λ and the velocity v in the cylindrical barrel, we have:

$$v = \frac{s_0 I_K}{\varphi m} \frac{s_{av.}}{s_0} x, \tag{63}$$

and, since we have accepted the condition that $v = v_{ц}$, it follows that:

$$\frac{s_0 I_K}{\varphi m} \frac{s_{av.}}{s_0} x = \frac{s_0 I_K}{\varphi m} x_{ц},$$

from which:

$$x = \frac{x_{ц}}{\frac{s_{av.}}{s_0}} > x_{ц}. \tag{64}$$

From equations (59) and (60), we obtain the following relation between W and Λ and x:

$$\frac{dW}{W_\psi + W} = \frac{d\Lambda}{\Lambda_\psi + \Lambda} = \frac{1}{f\omega} \frac{\varphi m v dv}{\psi - \frac{v^2}{v_{пр}^2}}, \tag{65}$$

where $\psi = f(z)$ is expressed by the following binomial formula:

$$\psi = \varkappa z + \varkappa \lambda z^2 = \psi_0 + \varkappa \sigma_0 x + \varkappa \lambda x^2.$$

Upon substituting into the right-hand side of equation (65) the values for dv in accordance with equation (61) and for v in accordance with equation (63), and upon introducing the designation:

$$B_0 = \frac{s_0^2 I_K^2}{f\omega\varphi m},$$

we obtain:

$$\frac{d\Lambda}{\Lambda_\psi + \Lambda} = \frac{B_0 \frac{s_{av.}}{s_0} \frac{s}{s_0} x dx}{\Psi_0 + \varkappa G_0 x - \left[B_0 \left(\frac{s_{av.}}{s_0}\right)^2 \frac{\theta}{2} - \varkappa\lambda\right] x^2} = \frac{B_0 \frac{s_{av.}}{s_0} \frac{s}{s_0} x dx}{\Psi_0 + k_1 x - B_{1s} x^2}, \tag{66}$$

where:

$$B_{1s} = \frac{B_0 \theta}{2} \left(\frac{s_{av.}}{s_0}\right)^2 - \varkappa\lambda.$$

The analogous equation for a cylindrical barrel of caliber d_0 has the following form:

$$\frac{d\Lambda}{\Lambda_\psi + \Lambda} = \frac{B_0 x_u dx_u}{\Psi_0 + k_1 x_u - B_1 x_u^2}, \tag{67}$$

where:

$$B_1 = \frac{B_0 \theta}{2} - \varkappa\lambda,$$

and B_0 is the same as above:

$$B_0 = \frac{s_0^2 I_K^2}{f\omega\varphi m}.$$

Comparison of expressions (66) and (67) shows that the parameters B_0 and B_1, which are constant for the cylindrical barrel, become in equation (66) for the conical barrel variable and dependent upon the variation in the cross section of the barrel.

But the product $\frac{s_{av.}}{s_0}$ $\frac{s}{s_0}$ in the numerator of formula (66) is a function of Λ and can be transferred to the left-hand side during integration, while the last term in the denominator is relatively small in comparison with the sum of the first two, and the variable

quantity $\left(\frac{s_{av.}}{s_0}\right)^2$ therein may be assumed to equal an average value, either one and the same for the entire interval of integration or different depending upon the quantity x.

In this case, equation (66) can be integrated, and the relation between Λ and x can be obtained in its final form.

On the basis of the above discussion:

$$\frac{s}{s_0} = y^2; \quad \frac{s_{av.}}{s_0} \approx y; \qquad \frac{s_{av.}}{s_0}\frac{s}{s_0} = y^3 = 1 - \frac{\Lambda}{\Lambda_{con.}} = f(\Lambda).$$

Separating the variables, we obtain:

$$\frac{d\Lambda}{(\Lambda_{\psi}+\Lambda)\left(1 - \frac{\Lambda}{\Lambda_{con.}}\right)} = \frac{B_0 x dx}{\Psi_0 + k_1 x - B_{1s}x^2} = -\frac{B_0}{B_{1s}}\frac{xdx}{x^2 - \frac{k_1}{B_{1s}}x - \frac{\Psi_0}{B_{1s}}}. \tag{68}$$

The right-hand side of equation (68) shows no external differences from the right-hand side of a similar equation for the cylindrical barrel and represents a differential of the function of Professor N. F. Drozdov (in which connection, during integration, B_{1s} must be taken as an average value $\bar{B}_{1s}$ over the given interval of integration):

$$-\frac{B_0}{\bar{B}_{1s}}\int_0^x \frac{xdx}{x^2 - \frac{k_1}{\bar{B}_{1s}}x - \frac{\Psi_0}{\bar{B}_{1s}}} = \ln Z_x^{-\frac{B_0}{\bar{B}_{1s}}},$$

This function is found from the basic quantities:

$$\gamma = \frac{\bar{B}_{1s}\Psi_0}{k_1^2}, \quad \beta = \frac{\bar{B}_{1s}}{k_1}x,$$

the magnitude of $\bar{B}_{1s}$ either varied in moving from one value of x to another or else being retained constant for the entire first period.

The left-hand side of equation (68) is likewise capable of integration at $\Lambda_\psi = \Lambda_{\psi av.}$, in which connection $\Lambda_{\psi av.}$ may likewise be taken either constant for all values of ψ, or else, which is better, its own value is taken each time for each value of $\psi = \psi_0 + k_1 x + \varkappa\lambda x$ used (as is commonly done to obtain a more exact solution at an average l_ψ). We resolve the function under the integral on the left-hand side of equation (68) into the simplest fractions:

$$\frac{1}{(\Lambda_{\psi av.}+\Lambda)\left(1-\frac{\Lambda}{\Lambda_{con.}}\right)} = \frac{\Lambda_{con.}}{(\Lambda_{\psi av.}+\Lambda)\,(\Lambda_{con.}-\Lambda)} = \frac{a}{\Lambda_{\psi av.}+\Lambda} + \frac{b}{\Lambda_{con.}-\Lambda};$$

$$\Lambda_{con.} = a\Lambda_{con.} - a\Lambda + b\Lambda_{\psi av.} + b\Lambda.$$

To determine a and b, we have two equations:

$$a\Lambda_{con.} + b\Lambda_{\psi av.} = \Lambda_{con.} \quad \text{and} \quad a - b = 0,$$

from which:

$$a = b \quad \text{and} \quad a + b\frac{\Lambda_{\psi av.}}{\Lambda_{con.}} = 1;$$

$$a = b = \frac{\Lambda_{con.}}{\Lambda_{\psi av.}+\Lambda_{con.}} = \frac{1}{1+\frac{\Lambda_{\psi av.}}{\Lambda_{con.}}}.$$

Consequently:

$$\frac{\Lambda_{con.}\,d\Lambda}{(\Lambda_{\psi av.}+\Lambda)(\Lambda_{con.}-\Lambda)} = \frac{\Lambda_{con.}}{\Lambda_{con.}+\Lambda_{\psi av.}}\left[\frac{d\Lambda}{\Lambda_{\psi av.}+\Lambda} - \frac{-d\Lambda}{\Lambda_{con.}-\Lambda}\right] =$$

$$= \frac{\Lambda_{con.}}{\Lambda_{con.}+\Lambda_{\psi av.}}\, d\ln\frac{\Lambda_{\psi av.}+\Lambda}{\Lambda_{con.}-\Lambda}.$$

By integrating equation (68) between the limits from zero to Λ and from zero to x, we obtain:

$$\left(\frac{1+\frac{\Lambda}{\Lambda_{\psi av.}}}{1-\frac{\Lambda}{\Lambda_{con.}}}\right)^{\frac{\Lambda_{con.}}{\Lambda_{con.}+\Lambda_{\psi av.}}\cdot\frac{B_0}{B_{1s}}} = Z_x \tag{69}$$

or, introducing the designation:

$$\frac{B_0}{B_{1s}}\left(1+\frac{\Lambda_{\psi av.}}{\Lambda_{con.}}\right) = A_K,$$

$$\frac{1+\frac{\Lambda}{\Lambda_{\psi av.}}}{1-\frac{\Lambda}{\Lambda_{con.}}} = Z_x^{-A_K}. \tag{70}$$

By solving equation (69) with respect to Λ, we obtain:

$$\Lambda = \Lambda_{\psi av.}\frac{Z_x^{-A_K}-1}{1+\frac{\Lambda_{\psi av.}}{\Lambda_{con.}}Z_x^{-A_K}}. \tag{71}$$

For the cylindrical barrel, we had:

$$\Lambda_{ц} = \Lambda_{\psi av.}\left(Z_x^{-\frac{B_0}{B_1}}-1\right), \tag{72}$$

where:

$$B_1 = \frac{B\theta}{2} - \varkappa\lambda.$$

The numerator of formula (71) for the conical barrel has the same form, with the sole difference that the exponent $\frac{B_0}{B_1}$ is replaced by the exponent:

$$A_K = \frac{B_0}{B_{1s}}\left(1+\frac{\Lambda_{\psi av.}}{\Lambda_{con.}}\right),$$

where:

$$\bar{B}_{1s} = \frac{B\theta}{2}\left(\frac{s_{av.}}{s_0}\right)^2 - \kappa\lambda.$$

is not constant, but varies depending upon the variation in the cross section of the bore. Moreover, there is present a denominator greater than unity, which increases as the powder burns during the motion of the projectile through the conical barrel.

Thus, formula (70) reflects the influence of the variable cross section of the bore and of those specific features which make their appearance as the projectile moves through the conical barrel.

The formula for the pressure will have the following form:

$$p = f\Delta \frac{\psi - \frac{v^2}{v^2_{\Pi p}}}{\Lambda_\psi + \Lambda} = f\Delta \frac{\psi_0 + k_1 x - B_{1s}x^2}{\Lambda_\psi + \Lambda}, \qquad (73)$$

i.e., its structure does not differ from that of the formula for the cylindrical barrel. Since, for definite values of x or ψ, the velocity $v < v_{ц}$, $\Lambda < \Lambda_{ц}$ for the conical barrel, the pressure in the conical bore exceeds that in the cylindrical barrel ($p > p_{ц}$).

Formula (73) can be written in the following form:

$$p = f\Delta \frac{\psi - \frac{B_0\theta}{2}\left(\frac{s_{av.}}{s_0}\right)^2 x^2}{\Lambda_\psi + \Lambda} \qquad (74)$$

By differentiating it with respect to x and equating the derivative to zero, we obtain a formula for x_m at which the gas pressure reaches its maximum.

Without presenting a detailed derivation, we shall write down the formula in its final form:

$$x_m = \frac{k_1}{\dfrac{B_0\left(\dfrac{s_{av.}}{s_0}\right)_m^2\left[\left(\dfrac{s_{av.}}{s_0}\right)_m + \theta\right]}{1 + \dfrac{p_m}{f}\left(a - \dfrac{1}{\delta}\right)} - 2\kappa\lambda};$$

At s = const., this formula becomes transformed into the usual formula for the cylindrical bore.

The appearance of the $p - \Lambda$ and $v - \Lambda$ curves is represented in Fig. 188.

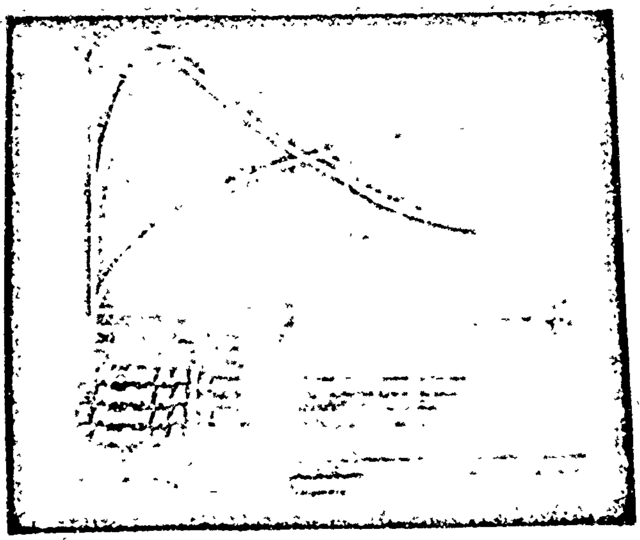


Fig. 188 - $p - \Lambda$ and $v - \Lambda$ Curves in Conical and Cylindrical Bores.

1) $p - \Lambda$ Curve, 1') $v - \Lambda$ Curve — in gun with cylindrical bore
2) $p - \Lambda$ Curve, 2') $v - \Lambda$ Curve — in gun with conical bore

In the method described above, there was accepted and utilized the proposition that the $v - \Lambda$ curves in the conical and cylindrical barrels coincide. In this connection, the quantity $x = z - z_0$ was taken as the argument. But if the quantity Λ is taken as the argument, the same formulas can be used as a basis to give a different order of computation of the elements of the curves, which has been proposed by I. M. Belenky. Knowing and assigning the quantity

and the corresponding values of $\frac{s}{s_0}$ and $\frac{s_{av.}}{s_0}$, and assuming in the first approximation for the computation of $\Lambda_{\psi av.}$ the value $\psi = 1$ and $\psi_{av.} = \frac{\psi_0 + 1}{2}$, it is possible to compute the function:

$$\log Z_x^{-1} = \frac{1}{A_K} \log \frac{1 + \frac{\Lambda}{\Lambda_{\psi av.}}}{1 - \frac{\Lambda}{\Lambda_{con.}}}, \tag{75}$$

where:

$$A_K = \frac{B_0}{B_{1s}} \left(1 + \frac{\Lambda_{\psi av.}}{\Lambda_{con.}}\right) \text{ and } \quad \bar{B}_{1s} = \frac{B_0 \Theta}{2} \left(\frac{s_{av.}}{s_0}\right)^2 - \varkappa\lambda.$$

Thereupon, from the table of the function $\log Z_x^{-1}$ and the quantity $\gamma = \frac{B_{1s}}{k_1^2} \psi_0$, there are found the values of $\beta = \frac{B_{1s}}{k_1} x$, from which $x = \frac{k_1}{B_{1s}} \beta$.

Since $\Lambda_{\psi av.}$ enters into the first part of formula (75), while ψ is not known in advance, it becomes necessary in the initial computations to accept an average value of $\psi = \frac{1}{2}$, which is correct only for the end of burning of the powder and introduces an error in determining the elements of the intermediate points of the first period. For these points, the pressure is obtained higher than is actually the case. It is necessary to proceed for these points by the method of successive approximations, the number of approximations being reducible to two if we assume $\psi = \left(\frac{\Lambda}{\Lambda_K}\right)^{2/3}$, where $\Lambda_K = \frac{W_K}{W_0}$ is the relative volume of the bore in the instant of the end of burning of the powder, and $\Lambda = \frac{W}{W_0}$ is the current value of the relative volume.

The character of the variation of Λ_ψ and $\Lambda_{\psi av.}$ and their influence upon the magnitude of the pressure are apparent from the diagram in Fig. 189.

GRAPHIC NOT REPRODUCIBLE

Fig. 189 - Dependence of Λ_{ψ} upon Λ in Conical Bore.
1) at; 2) period.

The actual values of $\Lambda_{\psi\,av.}$ vary as a function of Λ along a certain curve ab; acceptance of $\psi_0 = \frac{1}{2}$ for all points of the first period gives a straight line parallel to the abscissa.

The formulas for the second period have the usual form:

$$p = p_K\left(\frac{W_1 + W_K}{W_1 + W}\right)^{1+\theta} = p_K\left(\frac{1 - \alpha\Delta + \Lambda_K}{1 - \alpha\Delta + \Lambda}\right)^{1+\theta},$$

where:

$$W_1 = W_0(1 - \alpha\Delta) \quad \text{and} \quad \Lambda > \Lambda_K.$$

$$v = v_{np}\sqrt{1 - \left(\frac{1 - \alpha\Delta + \Lambda_K}{1 - \alpha\Delta + \Lambda_D}\right)^{\theta}\left(1 - \frac{v_K^2}{v_{np}^2}\right)},$$

where:

$$v_{np} = \sqrt{\frac{2gf\omega}{\varphi_K \theta q}} \quad \text{and} \quad v_K = \frac{s_0 I_K}{\varphi_K m}\,\frac{s_{K\,av.}}{s_0}(1 - z_0).$$

CHAPTER 3 - BALLISTIC DESIGN OF CONICAL BARREL

Since conical guns will be employed only for the purpose of attaining very high initial projectile velocities under conditions

when ordinary guns have an excessive length, we shall find in our design a conical barrel which corresponds to a cylindrical barrel with the minimum bore volume. For this reason, such a design will be based on the procedure and auxiliary tables presented in the division entitled "Ballistic Design of Guns".

On the basis of tactical and technical requirements, let there be predetermined the exit caliber d_D, the weight of the projectile q, and the initial projectile velocity v_D for the conical barrel.

Additionally, we determine $c_{qD} = \frac{q}{d_D^3}$; $\frac{v_D^2}{2g}$; and $C_\varepsilon = c_{qD}\frac{v_D^2}{2g}$. Since c_{qD} for armor-piercing projectiles may fluctuate in the range of 16-18, while the limit for the minimum c_{q0} based on the entrance caliber equals 6.0-7.0, the possible values for the ratios of the entrance to the exit caliber lie within rather narrow limits, namely:

$$\beta = \frac{d_0}{d_D} = \sqrt[3]{\frac{c_{qD}}{c_{q0}}} = \sqrt[3]{\frac{16}{7} \ldots \frac{18}{6}} = 1.32 \ldots 1.44.$$

In German guns, the accepted ratios are $\beta = 1.4$ for the 28/20 gun and $\beta = 1.363$ for the 75/55 gun.

The ratio:

$$\beta = \sqrt[3]{\frac{16}{6}} = \sqrt[3]{\frac{18 \cdot 67}{7}} = 1.385$$

may be recommended.

After selecting the entrance caliber d_0 in such a manner as to obtain c_{q0} = about 6.0, we find the fundamental characteristics of the minimum-volume cylindrical gun at $c_q = 6.0$ and at the chosen values of v_D and p_m:

$$\eta_{\omega_0} = 85 - 82 \text{ tm/kg}; \quad \frac{\omega_0}{q}; \quad \varphi_K = a_K + b_K\frac{\omega}{q}, \text{ where } a_K \approx 1.20;$$

$$b = 0.222; \quad v_{tab.D} = \frac{v_D}{n}; \quad n = \sqrt{\frac{\omega_0}{\varphi_K q}};$$

From the GAU Tables, we find:

$$B,\ \Lambda_K,\ \Lambda_D,\ \eta_K = \frac{\Lambda_K}{\Lambda_D};\ \frac{l_0}{d};\ W_0,\ \frac{L'_{KH}}{d_0} = \frac{l_0}{d} \cdot (\Lambda_D + 1);\ \frac{l_D}{d_0} = \frac{l_0}{d} \cdot \Lambda_D.$$

Here, $d = d_0$ equals the entrance caliber of the conical gun.

On the basis of these data, we determine the chamber volume $W_0 = s_0 l_0$, where $s_0 = n_s d_0^2$. The working volume of the bore is $W_D = s_0 l_D$, and this volume will be equal to the volume of the cone. Knowing the volume of the truncated cone W_D and the ratio of its diameters $y_D = \frac{d_D}{d_0}$, we use the formula $W_D = W_{con.}(1 - y_D^3)$ to find the volume of the entire cone to its apex:

$$W_{con.} = \frac{W_D}{1 - y_D^3}.$$

Since for the truncated cone:

$$W_D = s_{av.} l_D = s_0 \frac{1 + y_D + y_D^2}{3} l_D,$$

it follows that the length of the path of the projectile through the conical bore is:

$$l_D = \frac{3W_D}{s_0(1 + y_D + y_D^2)} \quad \text{and} \quad \tan\beta = \frac{d_0 - d_D}{2l_D}.$$

After designating:

$$\chi = \frac{l_0}{l_{KM}},$$

we find:

$$\frac{l_0}{\chi} = l_{KM} \quad \text{and} \quad L_{KH} = l_{KM} + l_D$$

and finally the total length of the barrel:

$$L_{CT} = L_{KII} + 2d_0$$

($2d_0$ being reserved for the breechblock).

Having assigned $\Lambda_m = 0.6$ and found $W_m = 0.6W_0$, we determine:

$$y_m = \sqrt[3]{1 - \frac{W_T}{W_{con.}}} \quad \text{and} \quad \frac{\bar{s}_{av.m}}{s_0} = \frac{1 + y_m}{2} .$$

We find $\frac{J_K}{d_0} = \frac{I_{K,\text{Ц}}}{d} \frac{s_0}{\bar{s}_{av.\ m}}$ or the pressure impulse $I_K = I_{K,\text{Ц}0} \frac{s_0}{s_{av.\ m}}$ which ensures attainment of the predetermined pressure p_m. As is shown by theory, the end of burning will be transferred closer to the start of motion of the projectile, and $\eta_K = \frac{W_K}{W_D}$ in the conical barrel will be smaller than $\eta_{K\text{Ц}} = \frac{W_K}{W_D} \quad \frac{l_{K\text{Ц}}}{l_{D\text{Ц}}}$ in the cylindrical barrel.

To compute the pressure and velocity curves for the conical barrel, we first compute and construct the v - W or v - Λ curve for the cylindrical barrel found. This is done most simply with the aid of the ANII or 1942 GAU Tables.

On the oasis of the values for v obtained in this manner, we compute the values of $x_\text{Ц} = \frac{v}{v_0}$, where $v_0 = \frac{s_0 I_K}{\varphi m}$ is the velocity of the projectile at the end of burning of the powder in the absence of any pressure to overcome the inertia of the projectile.

From the values of W corresponding to the values of v taken from the curve for the cylindrical barrel, we successively find the values of:

$$y = \sqrt[3]{1 - \frac{W}{W_{con.}}} ,$$

where:

$$W_{con.} = \frac{W_D}{1 - y_D^3} ; \quad \frac{s_{av.}}{s_0} = \frac{1 + y + y^2}{3} \approx y$$

By dividing the values of x_u by $\frac{s_{av.}}{s_u}$, we find for the same v and W the values of $x = \frac{x_u}{s_{av.}/s_u}$ for the conical barrel.

The quantity $x_K = 1 - z_0$ will indicate the volume W_K and the velocity v_K in the conical barrel at the end of burning of the powder.

On the basis of the resulting values of x, we find:

$$\psi = \psi_0 + \varkappa \sigma_0 x + \varkappa \lambda x^2$$

and the pressure:

$$p = f\omega \frac{\psi - \frac{v^2}{v^2_{np}}}{W_\psi + W} = f\Delta \frac{\psi - \frac{v^2}{v^2_{np}}}{\Lambda_\psi + \Lambda},$$

where:

$$W_\psi = W_0\left(1 - \frac{\Delta}{\delta}\right) - \omega\left(\alpha - \frac{1}{\delta}\right)\psi; \qquad \Lambda_\psi = 1 - \frac{\Delta}{\delta} - \Delta\left(\alpha - \frac{1}{\delta}\right)\psi,$$

and v and W are the same as for the cylindrical barrel.

For the end of the first period, $\psi_K = 1$.

$$p_K = f\omega \frac{1 - \frac{v^2}{v^2_{np}}}{W_1 + W_K} = f\Delta \frac{1 - \frac{v_K^2}{v^2_{np}}}{1 - \alpha\Delta + \Lambda_K}.$$

We find the muzzle velocity and muzzle pressure with the aid of the following formulas:

$$v_D^2 = v_{np}^2\left[1 - \left(1 - \frac{v_K^2}{v^2_{np}}\right)\left(\frac{1 - \alpha\Delta + \Lambda_K}{1 - \alpha\Delta + \Lambda_D}\right)^{\theta}\right];$$

$$p_D = p_K\left(\frac{1 - \alpha\Delta + \Lambda_K}{1 - \alpha\Delta + \Lambda_D}\right)^{1+\theta}$$

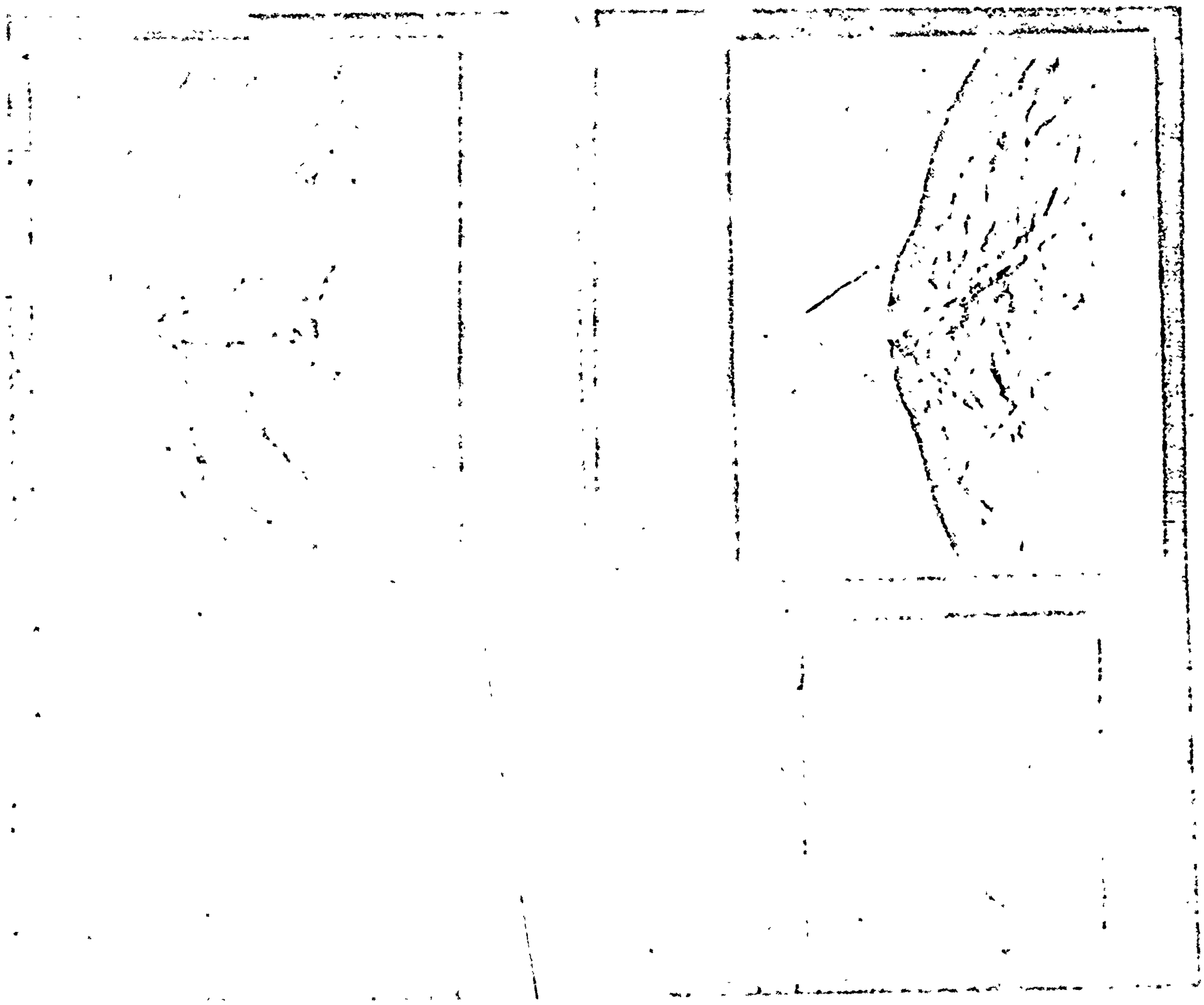
$$v^2_{np} = \frac{2g}{\varphi}\frac{f}{\theta}\frac{\omega}{q}$$

We determine the coefficient of utilization of the unit weight of the charge:

$$\eta_\omega = \frac{mv_D^2}{2\omega} = \frac{v_D^2}{2g} : \frac{\omega}{q} .$$

The velocity is obtained very close to the predetermined velocity for the cylindrical bore at the same volumes W_D and W_0 and under the same loading conditions except for I_K.

On the basis of the computed results obtained, there is, whenever necessary, applied a correction in order to obtain the required initial projectile velocity at the predetermined pressure p_m.



Figs. 116 - 119 - Spark Photographs of Bullet in Flight.

APPENDIX 1: TABLES FOR DETERMINING BURNT PART OF CHARGE ψ DURING BURNING OF POWDER IN CONSTANT VOLUME (BOMB)

(Compiled by M. E. Serebryakov)

On the basis of the general formula of pyrostatics, the part of the charge ψ burnt prior to any given moment can be computed with the aid of the following formula:

$$\psi = \frac{\dfrac{p - p_B}{p_m - p_B}}{\dfrac{p - p_B}{p_m - p_B}(1 - \partial) + \partial},$$

where:

$$\partial = \frac{1 - \alpha\Delta}{1 - \dfrac{\Delta}{\delta}}.$$

In these formulas, the following designations are used.

Δ is the loading density in the experiment.

δ is the density (specific gravity) of the powder.

α is the covolume of the powder gases.

p_m is the maximum pressure in the given experiment.

p_B is the pressure due to the igniter gases.

p is the pressure in a certain intermediate instant, which varies in the range of p_B-p_m.

Thus, the quantity ψ is a function of two parameters.

1) The parameter ∂, which is constant for the given experiment.

2) The variable ratio $\frac{p - p_B}{p_m - p_B}$, which varies from 0 to 1.

At α close to 1, δ close to 1.6, and Δ varying from 0.25 to 0, the quantity ∂, which depends upon the three quantities α, δ, and Δ,

varies in the range of 0.86-1.00.

The tables are compiled for every value of ∂ from 0.86 to 0.97 at intervals of 0.01, as related to the ratio $\frac{p - p_B}{p_m - p_B}$ varied from 0 to 1 at intervals of 0.001.

The arrangement of the tables is analogous to the arrangement of four-place logarithms.

USE OF TABLES

To start with, the experimental data are used to compute the basic quantity ∂ in accordance with the following formula:

$$\partial = \frac{1 - \alpha\Delta}{1 - \frac{\Delta}{\delta}}.$$

If the quantities α and δ are not known in advance, it may be approximately assumed that $\delta = 1.6$ and $\alpha = 1$ for pyroxylin powders and 0.8 for nitroglycerol powders.

Having computed the basic quantity ∂, we find the corresponding table of ψ as a function of the ratio $\frac{p - p_B}{p_m - p_B}$, which, for brevity has been designated as β in the tables:

$$\frac{p - p_B}{p_m - p_B} = \beta.$$

Having found in the left-hand column of the page the first two digits of the quantity β (tenths and hundredths), and taking from the upper row of the table the number corresponding to the thousandths of β (from 0 to 9), we find the quantity ψ for the first three digits of β at the intersection of this column with the row corresponding to the first two digits of β.

The change in ψ corresponding to the fourth digit of β after the decimal point is found by interpolating values for ψ between the

quantity found above and the neighboring quantity on the right.

Having obtained columns for the values of the time t and pressure p by treatment of the experimental p-t curve, and knowing the pressure p_B developed by the igniter and the maximum pressure p_m, we compute for every value of p a column of values of:

$$\beta = \frac{p - p_B}{p_m - p_B},$$

where $p_m - p_B$ will be a constant for the given experiment.

Having computed the ratio ∂ for the given experiment, we immediately find in the corresponding table the column of values of ψ, whereupon we can set up a column for the values of $\Delta\psi$ and a column for the values of the ratio $\frac{\Delta\psi}{\Delta t}$, which expresses the rate of gas formation from the given powder under the given conditions, which enters into the expression for the experimental characteristic of the progressivity of burning:

$$\Gamma = \frac{1}{p}\frac{\Delta\psi}{\Delta t}.$$

Example. Let there be known from preliminary experiments the quantities $\alpha = 0.97$ and $\delta = 1.58$, as well as the loading density in the given experiment $\Delta = 0.20$. In this connection, there have been obtained $p_B = 40$ kg/cm^2, $p_m = 2170$ kg/cm^2.

Let us determine the basic quantity ∂:

$$\partial = \frac{1 - \alpha\Delta}{1 - \frac{\Delta}{\delta}} = \frac{1 - 0.97 \cdot 0.20}{1 - \frac{0.20}{1.58}} = \frac{1 - 0.194}{1 - 0.1266} = \frac{0.806}{0.8734} = 0.9235.$$

We shall make use of the table corresponding to the nearest basic quantity ∂ in the tables, i.e. $\partial = 0.92$ (p. 1044).

Let the values for the pressure in any desired instants of time be:

$$p_1 = 204 \text{ and } p_2 = 1380.$$

We find the values:

$$\beta_1 = \frac{204 - 40}{2170 - 40} = \frac{164}{2130} = 0.0770;$$

$$\beta_2 = \frac{1380 - 40}{2170 - 40} = \frac{1340}{2170} = 0.6292.$$

To determine the value ψ_1, we find in the left-hand column of the table for $\partial = 0.92$ the ratio 0.07; in the upper row we find the number 7; and at the intersection of these horizontal and vertical lines we find the number 0.0834. Consequently, $\psi_1 = 0.0834$.

To determine ψ_2 corresponding to $\beta_2 = 0.6292$, we find the numbers 0.62 in the left-hand column and the number 9 in the upper row. The intersection of these will give the number 0.6483, which corresponds to the value of $\beta = 0.629$. The next larger value, $\beta = 0.630$, is associated with $\psi = 0.6493$. The difference between this and the first value equals 0.0010; it corresponds to 10 units of the forth digit of β; two units would correspond to $\Delta\psi = 0.0002$.

Thus, we shall have:

$$\begin{array}{ll} \beta = 0.629 & \left.\begin{array}{l}\psi = 0.6483 \\ \psi = 0.6493\end{array}\right\} \Delta\psi = 0.0010 \\ \beta = 0.630 & \\ \Delta\beta = 0.0002 & \Delta\psi = 0.0002 \\ \beta_2 = 0.6292 & \psi_2 = 0.6483 + 0.0002 = 0.6485 \end{array}$$

Since, as a rule, the differences $\Delta\psi$ between two neighboring columns differ very little from 10, the entire interpolation is easily carried out mentally.

δ= 0.86

β	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.00	0.000	0.0012	0.0024	0.0036	0.0048	0.0060	0.0071	0.0083	0.0095	0.0107
0.01	0.0118	130	142	153	165	176	188	200	212	223
2	234	246	257	269	280	292	303	315	326	338
3	349	361	372	384	395	407	418	430	441	453
4	464	476	487	499	510	522	533	[illegible]	556	568
0.05	579	591	602	614	625	637	648	660	671	683
0.06	0694	706	717	729	740	751	762	774	785	797
7	0808	820	831	843	854	866	877	889	900	911
8	0922	933	944	956	967	978	989	1000	1012	1023
9	1034	1045	1056	1067	1078	1090	1101	1112	1124	1135
0.10	1146	1157	1168	1180	1191	1202	1213	1224	1235	1247
0.11	1258	1269	1280	1291	1303	1314	1325	1336	1348	1359
12	1370	1381	1392	1403	1415	1426	1437	1448	1460	1471
13	1482	1493	1504	1515	1527	1538	1549	1560	1572	1583
14	1594	1605	1616	1627	1638	1650	1661	1672	1683	1694
15	1705	1716	1727	1738	1749	1760	1771	1782	1793	1804
0.16	1815	1826	1837	1848	1859	1870	1881	1892	1903	1914
17	1925	1936	1947	1958	1969	1980	1991	2002	2013	2024
18	2035	2046	2057	2068	2079	2090	2100	2111	2122	2133
19	2144	2155	2165	2176	2187	2198	2209	2220	2230	2241
20	2252	2263	2273	2284	2295	2306	2317	2328	2338	2349
0.21	2360	2371	2381	2392	2403	2414	2425	2436	2446	2457
22	2468	2479	2489	2500	2511	2522	2533	2544	2554	2565
23	2576	2587	2597	2608	2619	2630	2641	2652	2662	2673
24	2684	2695	2705	2716	2727	2738	2749	2760	2770	2784
25	2792	2803	2813	2824	2835	2846	2857	2868	2878	2889
0.26	2900	2910	2921	2932	2943	2953	2964	2975	2985	2996
27	3007	3017	3028	3039	3050	3060	3071	3082	3092	3103
28	3114	3124	3135	3146	3156	3167	3177	3188	3199	3209
29	3220	3230	3241	3252	3262	3273	3283	3294	3305	3316
30	3326	3336	3347	3358	3368	3379	3389	3400	3411	3421
0.31	3432	3442	3453	3463	3474	3484	3495	3505	3516	3526
32	3537	3547	3558	3560	3579	3589	3600	3610	3621	3631
33	3642	3652	3663	3673	3684	3694	3705	3715	3726	3736
34	3747	3757	3768	3778	3789	3799	3810	3820	3831	3841
35	3851	3861	3872	3882	3893	3903	3914	3924	3935	3945
0.36	3955	3965	3976	3986	3997	4007	4018	4028	4039	4049
37	4059	4070	4080	4090	4101	4111	4121	4132	4142	4152
38	4162	4173	4183	4193	4204	4214	4224	4235	4245	4255
39	4265	4276	4286	4296	4307	4317	4327	4338	4348	4358
40	4368	4379	4389	4399	4410	4420	4430	4441	4451	4461
0.41	4471	4482	4492	4502	4512	4523	4533	4543	4553	4563
42	4573	4584	4594	4604	4614	4624	4634	4644	4654	4664
43	4674	4685	4695	4705	4715	4725	4735	4745	4755	4765
44	4775	4786	4796	4806	4816	4826	4836	4846	4856	4866
45	4876	4887	4897	4907	4917	4927	4937	4947	4957	4967
0.46	4977	4988	4998	5008	5018	5028	5038	5048	5058	5068
47	5078	5089	5099	5109	5119	5129	5139	5149	5159	5169
48	5179	5189	5199	5209	5219	5229	5239	5249	5259	5269

4	464	476	487	499	510	522	533	545	556	568
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0.11	1258	1269	1280	1291	1303	1314	1325	1336	1348	1359
12	1370	1381	1392	1403	1415	1426	1437	1448	1460	1471
13	1482	1493	1504	1515	1527	1538	1549	1560	1572	1583
14	1594	1605	1616	1627	1638	1650	1661	1672	1683	1694
15	1705	1716	1727	1738	1749	1760	1771	1782	1793	1804
0.16	1815	1826	1837	1848	1859	1870	1881	1892	1903	1914
17	1925	1936	1947	1958	1969	1980	1991	2002	2013	2024
18	2035	2046	2057	2068	2079	2090	2100	2111	2122	2133
19	2144	2155	2165	2176	2187	2198	2209	2220	2230	2241
20	2252	2263	2273	2284	2295	2306	2317	2328	2338	2349
0.21	2360	2371	2381	2392	2403	2414	2425	2436	2446	2457
22	2468	2479	2489	2500	2511	2522	2533	2544	2554	2565
23	2576	2587	2597	2608	2619	2630	2641	2652	2662	2673
24	2684	2695	2705	2716	2727	2738	2749	2760	2770	2784
25	2792	2803	2813	2824	2835	2846	2857	2868	2878	2889
0.26	2900	2910	2921	2932	2943	2953	2964	2975	2985	2996
27	3007	3017	3028	3039	3050	3060	3071	3082	3092	3103
28	3114	3124	3135	3146	3156	3167	3177	3188	3199	3209
29	3220	3230	3241	3252	3262	3273	3283	3294	3305	3316
30	3326	3336	3347	3358	3368	3379	3389	3400	3411	3421
0.31	3432	3442	3453	3463	3474	3484	3495	3505	3516	3526
32	3537	3547	3558	3560	3579	3589	3600	3610	3621	3631
33	3642	3652	3663	3673	3684	3694	3705	3715	3726	3736
34	3747	3757	3768	3778	3789	3799	3810	3820	3831	3841
35	3851	3861	3872	3882	3893	3903	3914	3924	3935	3945
0.36	3955	3965	3976	3986	3997	4007	4018	4028	4039	4049
37	4059	4070	4080	4090	4101	4111	4121	4132	4142	4152
38	4162	4173	4183	4193	4204	4214	4224	4235	4245	4255
39	4265	4276	4286	4296	4307	4317	4327	4338	4348	4358
40	4368	4379	4389	4399	4410	4420	4430	4441	4451	4461
0.41	4471	4482	4492	4502	4512	4523	4533	4543	4553	4563
42	4573	4584	4594	4604	4614	4624	4634	4644	4654	4664
43	4674	4685	4695	4705	4715	4725	4735	4745	4755	4765
44	4775	4786	4796	4806	4816	4826	4836	4846	4856	4866
45	4876	4887	4897	4907	4917	4927	4937	4947	4957	4967
0.46	4977	4988	4998	5008	5018	5028	5038	5048	5058	5068
47	5078	5089	5099	5109	5119	5129	5139	5149	5159	5169
48	5179	5189	5199	5209	5219	5229	5239	5249	5259	5269
49	5279	5289	5299	5309	5319	5329	5339	5349	5359	5369
0.50	5379	5389	5399	5409	5419	5429	5439	5449	5459	5469

β	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.51	0.5478	0.5487	0.5497	0.5507	0.5517	0.5527	0.5537	0.5547	0.5557	0.5567
52	5577	5586	5596	5606	5616	5626	5636	5646	5656	5666
53	5676	5685	5695	5705	5715	5725	5734	5744	5754	5764
54	5774	5783	5793	5803	5813	5823	5832	5842	5852	5862
55	5872	5881	5891	5901	5910	5920	5930	5939	5949	5959
0.56	5969	5978	5988	5998	6007	6017	6027	6036	6046	6056
57	6066	6075	6085	6095	6104	6114	6124	6133	6143	6153
58	6163	6172	6182	6192	6201	6211	6221	6230	6240	6250
59	6260	6269	6279	6289	6298	6308	6317	6327	6336	6346
60	6356	6365	6375	6385	6394	6404	6413	6423	6432	6442
0.61	6452	6461	6471	6481	6490	6500	6510	6519	6529	6538
62	6548	6557	6567	6577	6586	6596	6606	6615	6625	6634
63	6644	6653	6663	6673	6682	6692	6702	6711	6721	6732
64	6740	6749	6759	6768	6778	6787	6797	6806	6816	6825
65	6835	6844	6854	6863	6873	6882	6892	6901	6911	6920
0.66	6930	6939	6949	6958	6968	6977	6986	6996	7005	7015
67	7024	7033	7043	7052	7062	7071	7080	7090	7099	7109
68	7118	7127	7137	7146	7156	7165	7174	7184	7193	7203
69	7212	7221	7231	7240	7250	7259	7268	7278	7287	7297
70	7306	7315	7325	7334	7344	7353	7362	7372	7381	7391
0.71	7400	7409	7419	7428	7438	7447	7456	7466	7475	7485
72	7494	7503	7513	7522	7532	7541	7550	7560	7569	7579
73	7588	7597	7607	7616	7626	7635	7644	7654	7663	7673
74	7682	7691	7701	7710	7719	7728	7738	7747	7756	7765
75	7775	7784	7794	7803	7812	7821	7831	7840	7849	7858
0.76	7868	7877	7886	7896	7905	7914	7923	7932	7941	7951
77	7960	7969	7978	7988	7997	8006	8015	8024	8033	8043
78	8052	8061	8070	8080	8089	8098	8107	8116	8126	8135
79	8144	8153	8162	8172	8181	8190	8199	8208	8218	8227
80	8236	8246	8255	8264	8273	8282	8291	8300	8309	8318
0.81	8327	8337	8346	8355	8364	8373	8382	8391	8400	8409
82	8418	8428	8437	8446	8355	8464	8473	8482	8491	8500
83	8509	8519	8528	8537	8546	8555	8564	8573	8582	8591
84	8600	8609	8618	8627	8636	8645	8654	8663	8672	8681
85	8690	8699	8708	8717	8726	8735	8744	8753	8762	8771
0.86	8780	8789	8798	8807	8816	8824	8833	8842	8851	8860
87	8869	8878	8887	8895	8904	8913	8922	8931	8938	8948
88	8957	8966	8975	8984	8992	9001	9010	9019	9027	9036
89	9045	9054	9062	9071	9080	9088	9097	9106	9114	9123
90	9132	9140	9149	9158	9167	9175	9184	9193	9201	9210
0.91	9219	9227	9236	9245	9254	9262	9271	9280	9289	9298
92	9306	9315	9323	9332	9341	9350	9359	9367	9376	9385
93	9394	9403	9411	9420	9429	9438	9447	9455	9464	9473
94	9482	9490	9492	9508	9517	9525	9534	9543	9552	9560
95	9568	9577	9585	9594	9603	9611	9620	9628	9637	9645
0.96	9654	9663	9671	9680	9689	9697	9706	9714	9723	9731
97	9740	9749	9757	9766	9775	9783	9792	9800	9809	9817
98	9826	9835	9843	9851	9860	9868	9877	9885	9894	9903
99	9912	9920	9929	9938	9947	9955	9964	9973	9982	9991
1.00	1.000									

0.56	5969	5978	5988	5998	6007	6017	6027	6036	6046	6056
57	6066	6075	6085	6095	6104	6114	6124	6133	6143	6153
58	6163	6172	6182	6192	6201	6211	6221	6230	6240	6250
59	6260	6269	6279	6289	6298	6308	6317	6327	6336	6346
60	6356	6365	6375	6385	6394	6404	6413	6423	6432	6442
0.61	6452	6461	6471	6481	6490	6500	6510	6519	6529	6538
62	6548	6557	6567	6577	6586	6596	6606	6615	6625	6634
63	6644	6653	6663	6673	6682	6692	6702	6711	6721	6732
64	6740	6749	6759	6768	6778	6787	6797	6806	6816	6825
65	6835	6844	6854	6863	6873	6882	6892	6901	6911	6920
0.66	6930	6939	6949	6958	6968	6977	6986	6996	7005	7015
67	7024	7033	7043	7052	7062	7071	7080	7090	7099	7109
68	7118	7127	7137	7146	7156	7165	7174	7184	7193	7203
69	7212	7221	7231	7240	7250	7259	7268	7278	7287	7297
70	7306	7315	7325	7334	7344	7353	7362	7372	7381	7391
0.71	7400	7409	7419	7428	7438	7447	7456	7466	7475	7485
72	7494	7503	7513	7522	7532	7541	7550	7560	7569	7579
73	7588	7597	7607	7616	7626	7635	7644	7654	7663	7673
74	7682	7691	7701	7710	7719	7728	7738	7747	7756	7765
75	7775	7784	7794	7803	7812	7821	7831	7840	7849	7858
0.76	7868	7877	7886	7896	7905	7914	7923	7932	7941	7951
77	7960	7969	7978	7988	7997	8006	8015	8024	8033	8043
78	8052	8061	8070	8080	8089	8098	8107	8116	8126	8135
79	8144	8153	8162	8172	8181	8190	8199	8208	8218	8227
80	8236	8246	8255	8264	8273	8282	8291	8300	8309	8318
0.81	8327	8337	8346	8355	8364	8373	8382	8391	8400	8409
82	8418	8428	8437	8446	8355	8464	8473	8482	8491	8500
83	8509	8519	8528	8537	8546	8555	8564	8573	8582	8591
84	8600	8609	8618	8627	8636	8645	8654	8663	8672	8681
85	8690	8699	8708	8717	8726	8735	8744	8753	8762	8771
0.86	8780	8789	8798	8807	8816	8824	8833	8842	8851	8860
87	8869	8878	8887	8895	8904	8913	8922	8931	8938	8948
88	8957	8966	8975	8984	8992	9001	9010	9019	9027	9036
89	9045	90[illegible]4	9062	9071	9080	9088	9097	9106	9114	9123
90	9132	9140	9149	9158	9167	9175	9184	9193	9201	9210
0.91	9219	9227	9236	9245	9254	9262	9271	9280	9289	9298
92	9306	9315	9323	9332	9341	9350	9359	9367	9376	9385
93	9394	9403	9411	9420	9429	9438	9447	9455	9464	9473
94	9482	9490	9492	9508	9517	9525	9534	9543	9552	9560
95	9568	9577	9585	9594	9603	9611	9620	9628	9637	9645
0.96	9654	9663	9671	9680	9689	9697	9706	9714	9723	9731
97	9740	9749	9757	9766	9775	9783	9792	9800	9809	9817
98	9826	9835	9843	9851	9860	9868	9877	9885	9894	9903
99	9912	9920	9929	9938	9947	9955	9964	9973	9982	9991
1.00	1.000	-	-	-	-	-	-	-	-	-

∂ ~ 0.87

t	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.00	0.000	0.0012	0.0024	0.0035	0.0047	0.0058	0.0070	0.0082	0.0093	0.0105
0.01	0.0116	128	138	150	162	173	185	196	207	219
2	230	242	253	264	276	287	299	310	321	133
3	344	356	367	378	390	401	412	424	435	446
4	457	469	480	491	503	514	525	537	548	559
5	570	582	593	604	616	627	638	650	661	672
0.06	683	695	706	717	729	740	751	763	774	785
7	796	808	819	830	341	852	864	875	886	897
8	908	920	931	942	953	964	976	987	998	1009
9	0.1020	1032	1043	1054	1065	1076	1088	1099	1110	1121
0.10	1132	1144	1155	1166	1177	1188	1200	1211	1222	1233
0.11	1244	1256	1267	1278	1289	1300	1312	1323	1334	1345
12	1356	1367	1378	1389	1400	1411	1422	1433	1444	1455
13	1466	1476	1487	1498	1509	1520	1531	1542	1553	1564
14	1575	1585	1596	1607	1618	1629	1640	1651	1662	1673
15	1684	1694	1705	1716	1727	1738	1749	1760	1771	1782
0.16	1793	1803	1814	1825	1836	1847	1858	1869	1880	1891
17	1902	1912	1923	1934	1945	1956	1967	1978	1989	2000
18	2011	2021	2032	2043	2054	2065	2076	2087	2098	2109
19	2120	2130	2141	2152	2163	2174	2184	2195	2206	2217
20	2228	2238	2249	2260	2271	2282	2292	2303	2314	2325
0.21	2336	2346	2357	2368	2379	2390	2400	2411	2423	2433
22	2444	2454	2465	2476	2487	2498	2508	2519	2530	2541
23	2552	2562	2573	2584	2594	2605	2616	2626	2637	2648
24	2659	2669	2680	2691	2701	2712	2723	2733	2744	2755
25	2766	2776	2787	2798	2808	2819	2830	2848	2851	2862
0.26	2873	2883	2894	2905	2915	2926	2937	2947	2958	2969
27	2980	2990	3001	3012	3023	3033	3043	3054	2064	3075
28	3086	3096	3107	3118	3128	3139	3149	3160	3170	3181
29	3192	3202	3213	3224	3234	3245	3255	3266	3276	3287
30	3298	3308	3319	3330	3340	3351	3361	3372	3382	3393
0.31	3404	3414	3425	3435	3446	3456	3467	3477	3488	3498
32	3509	3519	3530	3540	3551	3561	3572	3582	3593	3603
33	3614	3624	3635	3645	3655	3666	3676	3687	3697	3708
34	3718	3728	3739	3749	3759	3770	3780	3791	3801	3812
35	3822	3832	3843	3853	3863	3874	3884	3895	3905	3916
0.36	3926	3936	3947	3957	3967	3978	3988	3999	4009	4020
37	4030	4040	4050	4061	4071	4081	4092	4102	4112	4123
38	4133	4143	4153	4164	4174	4184	4195	4205	4215	4226
39	4236	4246	4256	4266	4276	4287	4297	4307	4317	4328
40	4338	4348	4358	4368	4378	4389	4399	4409	4419	4429
0.41	4440	4450	4460	4470	4480	4491	4501	4511	4521	4531
42	4542	4552	4562	4572	4582	4592	4603	4613	4623	4633
43	4643	4653	4663	4673	4683	4693	4704	4714	4724	4734
44	4744	4754	4764	4774	4784	4794	4805	4815	4825	4835
45	4845	4855	4865	4875	4885	4895	4906	4916	4926	4936
0.46	4946	4956	4966	4976	4986	4996	5007	5017	5027	5037
47	5047	5057	5067	5077	5087	5097	5108	5118	5128	5138

3	344	356	367	378	390	401	412	424	435	446
4	457	469	480	491	503	514	525	537	548	559
5	570	582	593	604	616	627	638	650	661	672
0.06	683	695	706	717	729	740	751	763	774	785
7	796	808	819	830	841	852	864	875	886	897
8	908	920	931	942	953	964	976	987	998	1009
9	0.1020	1032	1043	1054	1065	1076	1088	1099	1110	1121
0.10	1132	1144	1155	1166	1177	1188	1200	1211	1222	1233
0.11	1244	1256	1267	1278	1289	1300	1312	1323	1334	1345
12	1356	1367	1378	1389	1400	1411	1422	1433	1444	1455
13	1466	1476	1487	1498	1509	1520	1531	1542	1553	1564
14	1575	1585	1596	1607	1618	1629	1640	1651	1662	1673
15	1684	1694	1705	1716	1727	1738	1749	1760	1771	1782
0.16	1793	1803	1814	1825	1836	1847	1858	1869	1880	1891
17	1902	1912	1923	1934	1945	1956	1967	1978	1989	2000
18	2011	2021	2032	2043	2054	2065	2076	2087	2098	2109
19	2120	2130	2141	2152	2163	2174	2184	2195	2206	2217
20	2228	2238	2249	2260	2271	2282	2292	2303	2314	2325
0.21	2336	2346	2357	2368	2379	2390	2400	2411	2423	2433
22	2444	2454	2465	2476	2487	2498	2508	2519	2530	2541
23	2552	2562	2573	2584	2594	2605	2616	2626	2637	2648
24	2659	2669	2680	2691	2701	2712	2723	2733	2744	2755
25	2766	2776	2787	2798	2808	2819	2830	2848	2851	2862
0.26	2873	2883	2894	2905	2915	2926	2937	2947	2958	2969
27	2980	2990	3001	3012	3022	3033	3043	3054	2064	3075
28	3086	3096	3107	3118	3128	3139	3149	3160	3170	3181
29	3192	3202	3213	3224	3234	3245	3255	3266	3276	3287
30	3298	3308	3319	3330	3340	3351	3361	3372	3382	3393
0.31	3404	3414	3425	3435	3446	3456	3467	3477	3488	3498
32	3509	3519	3530	3540	3551	3561	3572	3582	3593	3603
33	3614	3624	3635	3645	3655	3666	3676	3687	3697	3708
34	3718	3728	3739	3749	3759	3770	3780	3791	3801	3812
35	3822	3832	3843	3853	3863	3874	3884	3895	3905	3916
0.36	3926	3936	3947	3957	3967	3978	3988	3999	4009	4020
37	4030	4040	4050	4061	4071	4081	4092	4102	4112	4123
38	4133	4143	4153	4164	4174	4184	4195	4205	4215	4226
39	4236	4246	4256	4266	4276	4287	4297	4307	4317	4328
40	4338	4348	4358	4368	4378	4389	4399	4409	4419	4429
0.41	4440	4450	4460	4470	4480	4491	4501	4511	4521	4531
42	4542	4552	4562	4572	4582	4592	460[illegible]	4613	4623	4633
43	4643	4653	4663	4673	4683	4693	4704	4714	4724	4734
44	4744	4754	4764	4774	4784	4794	4805	4815	4825	4835
45	4845	4855	4865	4875	4885	4895	4906	4916	4926	4936
0.46	4946	4956	4966	4976	4986	4996	5007	5017	5027	5037
47	5047	5057	5067	5077	5087	5097	5108	5118	5128	5138
48	5148	5158	5168	5178	5188	5198	5208	5218	5228	5238
49	5248	5258	5268	5278	5288	5298	5308	5318	5328	5338
50	5348	5358	5368	5378	5388	5398	5408	5418	5428	5438

$\partial = 0.87$

β	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.51	0.5447	0.5457	0.5467	0.5477	0.5487	0.5497	0.5507	0.5517	0.5527	0.5537
52	5546	5556	5566	5576	5586	5596	5606	5616	5626	5636
53	5645	5655	5665	5675	5685	5695	5705	5715	5725	5735
54	5744	5754	5764	5774	5784	5793	5803	5812	5823	5833
55	5842	5852	5862	5872	5882	5891	5901	5911	5921	5931
0.56	5940	5950	5960	5970	5980	5989	5999	6009	6019	6029
57	6038	6048	6058	6068	6078	6087	6097	6107	6117	6127
58	6136	6146	6156	6166	6175	6185	6195	6204	6214	6224
59	6233	6243	6253	6263	6272	6282	6292	6301	6311	6321
60	6330	6340	6350	6360	6369	6379	6389	6398	6408	6418
0.61	6427	6437	6447	6457	6466	6476	6486	6495	6505	6515
62	6524	6534	6544	6553	6563	6573	6582	6592	6601	6611
63	6620	6630	6640	6649	6659	6668	6678	6687	6697	6707
64	6716	6726	6736	6745	6755	6764	6774	6783	6793	6803
65	6812	6822	6832	6841	6851	6860	6870	6879	6889	6899
0.66	6908	6918	6928	6937	6947	6956	6966	6975	6985	6995
67	700'	7014	7023	7033	7042	7052	7061	7071	7080	7090
68	7099	7109	7118	7128	7137	7147	7156	7166	7775	7185
69	7194	7204	7213	7223	7232	7242	7251	7260	7270	7279
70	7288	7298	7307	7317	7326	7336	7345	7354	7364	7373
0.71	7382	7392	7401	7411	7420	7430	7439	7448	7458	7467
72	7476	7486	7495	7505	7514	7524	7533	7542	7552	7561
73	7570	7580	7589	7599	7608	7618	7627	7636	7646	7655
74	7664	7673	7682	7691	7701	7710	7719	7729	7738	7747
75	7757	7766	7775	7784	7794	7803	7812	7822	7831	7840
0.76	7850	7859	7868	7877	7887	7896	7905	7915	7924	7933
77	7943	7952	7961	7970	7980	7989	7998	8008	8017	8026
78	8036	8045	8054	8063	8072	8082	8091	8100	8109	8118
79	8128	8137	8146	8155	8164	8174	8183	8192	8201	8210
80	8220	8229	8238	8247	8256	8265	8275	8284	8293	8302
0.81	8311	8320	8329	8338	8347	8356	8366	8375	8384	8393
82	8402	8411	8420	8429	8438	8447	8457	8466	8475	8484
83	8493	8502	8511	8520	8529	8538	8547	8556	8565	8574
84	8583	8592	8601	8610	8619	8628	8637	8646	8655	8664
85	8673	8682	8691	8700	8709	8718	8727	8736	8745	8754
0.86	8763	8772	8781	8790	8799	8808	8817	8826	8835	8844
87	8853	8862	8871	8880	8889	8898	8907	8916	8925	8934
88	8943	8952	8961	8970	8979	8988	8997	9006	9015	9024
89	9033	9042	9051	9060	9069	9078	9087	9095	9104	9113
90	9122	9131	9140	9149	9158	9167	9176	9184	9193	9202
0.91	9211	9220	9229	9238	9247	9256	9265	9273	9282	9291
92	9300	9309	9317	9326	9335	9344	9353	9361	9370	9379
93	9388	9397	9405	9414	9423	9432	9441	9449	9458	9467
94	9476	9485	9493	9502	9511	9520	9529	9537	9546	9555
95	9564	9573	9581	9590	9599	9608	9617	9625	9634	9643
.96	9652	9660	9669	9678	9686	9695	9704	9712	9721	9730
97	9739	9747	9756	9765	9773	9782	9791	9799	9808	9817
98	9826	9834	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

55	5842	5852	5862	5872	5882	5891	5901	5911	5921	5931
0.56	5940	5950	5960	5970	5980	5989	5999	6009	6019	6029
57	6038	6048	6058	6068	6078	6087	6097	6107	6117	6127
58	6136	6146	6156	6166	6175	6185	6195	6204	6214	6224
59	6233	6243	6253	6263	6272	6282	6292	6301	6311	6321
60	6330	6340	6350	6360	6369	6379	6389	6398	6408	6418
0.61	6427	6437	6447	6457	6466	6476	6486	6495	6505	6515
62	6524	6534	6544	6553	6563	6573	6582	6592	6601	6611
63	6620	6630	6640	6649	6659	6668	6678	6687	6697	6707
64	6716	6726	6736	6745	6755	6764	6774	6783	6793	6803
65	6812	6822	6832	6841	6851	6860	6870	6879	6889	6899
0.66	6908	6918	6928	6937	6947	6956	6966	6975	6985	6995
67	7004	7014	7023	7033	7042	7052	7061	7071	7080	7090
68	7099	7109	7118	7128	7137	7147	7156	7166	7775	7185
69	7194	7204	7213	7223	7232	7242	7251	7260	7270	7279
70	7288	7298	7307	7317	7326	7336	7345	7354	7364	7373
0.71	7382	7392	7401	7411	7420	7430	7439	7448	7458	7467
72	7476	7486	7495	7505	7514	7524	7533	7542	7552	7561
73	7570	7580	7589	7599	7608	7618	7627	7636	7646	7655
74	7664	7673	7682	7691	7701	7710	7719	7729	7738	7747
75	7757	7766	7775	7784	7794	7803	7812	7822	7831	7840
0.76	7850	7859	7868	7877	7887	7896	7905	7915	7924	7933
77	7943	7952	7961	7970	7980	7989	7998	8008	8017	8026
78	8036	8045	8054	8063	8072	8082	8091	8100	8109	8118
79	8128	8137	8146	8155	8164	8174	8183	8192	8201	8210
80	8220	8229	8238	8247	8256	8265	8275	8284	8293	8302
0.81	8311	8320	8329	8338	8347	8356	8366	8375	8384	8393
82	8402	8411	8420	8429	8438	8447	8457	8466	8475	8484
83	8493	8502	8511	8520	8529	8538	8547	8556	8565	8574
84	8583	8592	8601	8610	8619	8628	8637	8646	8655	8664
85	8673	8682	8691	8700	8709	8718	8727	8736	8745	8754
0.86	8763	8772	8781	8790	8799	8808	8817	8826	8835	8844
87	8853	8862	8871	8880	8889	8898	8907	8916	8925	8934
88	8943	8952	8961	8970	8979	8988	8997	9006	9015	9024
89	9033	9042	9051	9060	9069	9078	9087	9095	9104	9113
90	9122	9131	9140	9149	9158	9167	9176	9184	9193	9202
0.91	9211	9220	9229	9238	9247	9256	9265	9273	9282	9291
92	9300	9309	9317	9326	9335	9344	9353	9361	9370	9379
93	9388	9397	9405	9414	9423	9432	9441	9449	9458	9467
94	9476	9485	9493	9502	9511	9520	9529	9537	9546	9555
95	9564	9573	9581	9590	9599	9608	9617	9625	9634	9643
.96	9652	9660	9669	9678	9686	9695	9704	9712	9721	9730
97	9739	9747	9756	9765	9773	9782	9791	9799	9808	9817
98	9826	9834	9843	9852	9860	9869	9878	9886	9895	9904
99	9913	9921	9930	9939	9947	9956	9965	9973	9982	9991
1.00	1,000	-	-	-	-	-	-	-	-	-

β	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.00	0.000	0.0012	0.0024	0.0035	0.0046	0.0058	0.0069	0.0081	0.0092	0.0103
1	0.0114	126	137	148	160	171	183	194	205	216
2	227	238	250	261	272	283	294	306	317	328
3	339	350	362	373	384	396	407	418	430	441
4	452	463	474	485	397	508	519	530	541	553
5	564	576	587	598	609	620	632	643	654	665
0.06	676	688	699	710	721	732	744	755	766	777
7	788	800	811	822	833	844	856	867	878	889
8	900	912	923	934	945	956	967	978	989	0.1000
9	0.1011	1023	1034	1045	1056	1067	1078	1089	1100	1111
0.10	1122	1133	1144	1155	1166	1177	1188	1199	1210	1221
0.11	1232	1243	1254	1265	1276	1287	1298	1309	1320	1331
12	1342	1353	1364	1375	1385	1396	1407	1418	1429	1440
13	1451	1462	1473	1484	1495	1505	1516	1527	1538	1549
14	1560	1571	1582	1593	1604	1615	1625	1636	1647	1658
15	1669	1680	1690	1701	1712	1723	1734	1745	1756	1767
0.16	1778	1789	1800	1810	1821	1832	1843	1854	1865	1876
17	1887	1898	1909	1920	1930	1941	1952	1963	1974	1985
18	1995	2006	2017	2027	2038	2049	2060	2070	2081	2092
19	2103	2114	2124	2135	2146	2156	2167	2178	2188	2199
20	2210	2221	2231	2242	2253	2263	2274	2285	2295	2306
0.21	2317	2328	2338	2349	2360	2370	2381	2392	2402	2413
22	2424	2435	2445	2456	2467	2477	2488	2499	2509	2520
23	2531	2542	2552	2563	2574	2584	2595	2606	2616	2627
24	2638	2648	2659	2670	2680	2691	2702	2712	2723	2733
25	2744	2754	2765	2776	2786	2797	2808	2818	2829	2839
0.26	2850	2860	2871	2882	2892	2903	2914	2924	2935	2940
27	2956	2966	2977	2988	2998	3009	3020	3030	3041	3051
28	3062	3072	3083	3094	3104	3115	3126	3136	3147	3157
29	3168	3178	3189	3199	3210	3220	3231	3241	3252	3262
30	3273	3283	3294	3304	3315	3325	3336	3346	3357	3367
0.31	3378	3388	3399	3409	3420	3430	3441	3451	3462	3472
32	3483	3493	3504	3514	3525	3535	3546	3556	3567	3577
33	3588	3598	3608	3619	3629	3640	3650	3661	3671	3682
34	3692	3703	3713	3723	3734	3744	3754	3765	3775	3785
35	3795	3806	3816	3826	3837	3847	3857	3868	3878	3888
0.36	3898	3908	3918	3929	3939	3950	3960	3971	3981	3992
37	4002	4013	4023	4033	4044	4054	4064	4075	4085	4095
38	4105	4116	4126	4136	4147	4157	4167	4178	4188	4198
39	4208	4219	4229	4239	4249	4259	4270	4280	4290	4300
40	4310	4321	4331	4341	4351	4361	4372	4382	4392	4402
0.41	4412	4423	4433	4443	4453	4463	4474	4484	4494	4504
42	4514	4525	4535	4545	4555	4565	4575	4585	4595	4605
43	4615	4626	4636	4646	4656	4666	4676	4686	4696	4706
44	4716	4727	4737	4747	4757	4767	4777	4787	4797	4807
45	4817	4828	4838	4848	4858	4868	4878	4888	4898	4908
0.46	4918	4928	4938	4948	4958	4968	4978	4988	4998	5008
47	5018	5028	5038	5038	5058	5068	5078	5088	5098	5108
48	5119	5129	5139	5149	5159	5169	5179	5189	5199	5209
49	5219	5229	5239	5249	[illegible]	[illegible]	[illegible]			

4	452	463	474	485	397	508	519	530	541	553
5	564	576	587	598	609	620	632	643	654	665
0.06	676	688	699	710	721	732	744	755	766	777
7	788	800	811	822	833	844	856	867	878	889
8	900	912	923	934	945	956	967	978	989	0.1000
9	0.1011	1023	1031	1045	1056	1067	1078	1089	1100	1111
0.10	1122	1133	1144	1155	1166	1177	1188	1199	1210	1221
0.11	1232	1243	1254	1265	1276	1287	1298	1309	1320	1331
12	1342	1353	1364	1375	1335	1396	1407	1418	1429	1440
13	1451	1462	1473	1484	1495	1505	1516	1527	1538	1549
14	1560	1571	1582	1593	1604	1615	1625	1636	1647	1658
15	1669	1680	1690	1701	1712	1723	1734	1745	1756	1767
0.16	1778	1789	1800	1810	1821	1832	1843	1854	1865	1876
17	1887	1898	1909	1920	1930	1941	1952	1963	1974	1985
18	1995	2006	2017	2027	2038	2049	2060	2070	2081	2092
19	2103	2114	2124	2135	2146	2156	2167	2178	2188	2199
20	2210	2221	2231	2242	2253	2263	2274	2285	2295	2306
0.21	2317	2328	2338	2349	2360	2370	2381	2392	2402	2413
22	2424	2435	2445	2456	2467	2477	2488	2499	2509	2520
23	2531	2542	2552	2563	2574	2584	2595	2606	2616	2627
24	2638	2648	2659	2670	2680	2691	2702	2712	2723	2733
25	2744	2754	2765	2776	2786	2797	2808	2818	2829	2839
0.26	2850	2860	2871	2882	2892	2903	2914	2924	2935	2940
27	2956	2966	2977	2988	2998	3009	3020	3030	3041	3051
28	3062	3072	3083	3094	3104	3115	3126	3136	3147	3157
29	3168	3178	3189	3199	3210	3220	3231	3241	3252	3262
30	3273	3283	3294	3304	3315	3325	3336	3346	3357	3367
0.31	3378	3388	3399	3409	3420	3430	3441	3451	3462	3472
32	3483	3493	3504	3514	3525	3535	3546	3556	3567	3577
33	3588	3598	3608	3619	3629	3640	3650	3661	3671	3682
34	3692	3703	3713	3723	3734	3744	3754	3765	3775	3785
35	3795	3806	3816	3826	3837	3847	3857	3868	3878	3888
0.36	3898	3908	3918	3929	3939	3950	3960	3971	3981	3992
37	4002	4013	4023	4033	4044	4054	4064	4075	4085	4095
38	4105	4116	4126	4136	4147	4157	4167	4178	4188	4198
39	4208	4219	4229	4239	4249	4259	4270	4280	4290	4300
40	4310	4321	4331	4341	4351	4361	4372	4382	4392	4402
0.41	4412	4423	4433	4443	4453	4463	4474	4484	4494	4504
42	4514	4525	4535	4545	4555	4565	4575	4585	4595	4605
43	4615	4626	4636	4646	4656	4666	4676	4686	4696	4706
44	4716	4727	4737	4747	4757	4767	4777	4787	4797	4807
45	4817	4828	4838	4848	4858	4868	4878	4888	4898	4908
0.46	4918	4928	4938	4948	4958	4968	4978	4988	4998	5008
47	5018	5028	5038	5038	5058	5068	5078	5088	5098	5108
48	5119	5129	5139	5149	5159	5169	5179	5189	5199	5209
49	5219	5229	5239	5249	5259	5269	5279	5289	5299	5309
0.50	5319	5329	5339	5349	5369	5399	5379	5389	5399	5409

∂ = 0.88

β	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.51	0.5418	0.5428	0.5438	0.5448	0.5458	0.5468	0.5478	0.5488	0.5498	0.5508
52	5518	5527	5537	5547	5557	5667	5577	5587	5597	5607
53	5617	5626	5636	5646	5656	5666	5676	5686	5696	5706
54	5716	5725	5735	5745	5755	5765	5774	5784	5794	5804
55	5814	5823	5833	5843	5853	5863	5872	5882	5892	5902
0.56	5912	5921	5931	5941	5951	5961	5970	5980	5990	6000
57	6010	6019	6029	6039	6049	6059	6068	6078	6088	6098
58	6108	6117	6127	6137	6146	6156	6166	6175	6185	6195
59	6205	6214	6224	6234	6243	6253	6262	6272	6282	6292
60	6302	6311	6321	6331	6340	6350	6360	6369	6379	6389
0.61	6399	6408	6418	6428	6437	6447	6457	6466	6476	6486
62	6496	6505	6515	6525	6534	6544	6554	6563	6573	6583
63	6593	6602	6612	6622	6631	6641	6651	6660	6670	6680
64	6690	6699	6709	6719	6728	6738	6748	6757	6767	6777
65	6787	6796	6806	6816	6825	6835	6845	6854	6864	6874
0.66	6883	6892	6902	6912	6921	6931	6941	6950	6960	6970
67	6979	6988	6998	7008	7017	7027	7037	7046	7056	7066
68	7075	7084	7094	7103	7113	7122	7132	7141	7151	7160
69	7170	7179	7189	7198	7208	7217	7227	7236	7246	7255
70	7265	7274	7284	7293	7303	7312	7322	7331	7341	7350
0.71	7360	7369	7379	7388	7397	7407	7416	7426	7435	7445
72	7454	7463	7472	7482	7491	7501	7510	7520	7529	7539
73	7548	7557	7567	7576	7585	7595	7604	7614	7623	7633
74	7642	7651	7661	7670	7679	7689	7698	7708	7717	7727
75	7736	7745	7755	7764	7773	7783	7792	7802	7811	7821
0.76	7830	7839	7848	7858	7867	7876	7886	7895	7904	7914
77	7923	7932	7941	7951	7960	7969	7979	7988	7997	8007
78	8016	8025	8034	8044	8053	8062	8072	8081	8090	8100
79	8109	8118	8127	8137	8146	8155	8165	8174	8183	8193
80	8202	8211	8220	8229	8238	8248	8257	8266	8275	8284
0.81	8294	8303	8312	8321	8330	8340	8349	8358	8367	8376
82	8385	8394	8403	8412	8421	8431	8440	8449	8458	8467
83	8476	8485	8494	8503	8512	8522	8531	8540	8549	8558
84	8567	8576	8585	8594	8603	8613	8622	8631	8640	8649
85	8658	8667	8676	8685	8694	8704	8713	8722	8731	8740
0.86	8740	8758	8767	8776	8785	8795	8804	8813	8822	8831
87	8840	8849	8858	8867	8876	8886	8895	8904	8913	8922
88	8931	8940	8949	8958	8967	8977	8986	8995	9004	9013
89	9022	9031	9040	9049	9058	9067	9076	9085	9094	9103
90	9112	9121	9130	9139	9148	9157	9166	9175	9184	9193
0.91	9202	9211	9220	9229	9238	9247	9256	9265	9274	9283
92	9292	9300	9309	9318	9327	9336	9345	9354	9363	9372
93	9381	9389	9398	9407	9416	9425	9434	9443	9452	9461
94	9470	9478	9487	9496	9505	9514	9522	9531	9540	9549
95	9558	9566	9575	9584	9593	9602	9610	9619	9628	9637
.96	9646	9654	9663	9672	9681	9690	9698	9707	9716	9725
97	9734	9743	9752	9760	9769	9778	9787	9796	9805	9814
98	9823	9832	9841	9849	9858	9867	9876	9885	9894	9903
99	9912	9920	9929	9938	9947	9956	9964	9973	9982	9991

55	5814	5823	5833	5843	5853	5863	5872	5882	5892	5902
0.56	5912	5921	5931	5941	5951	5961	5970	5980	5990	6000
57	6010	6019	6029	6039	6049	6059	6068	6078	6088	6098
58	6108	6117	6127	6137	6146	6156	6166	6175	6185	6195
59	6205	6214	6224	6234	6243	6253	6262	6272	6282	6292
60	6302	6311	6321	6331	6340	6350	6360	6369	6379	6389
0.61	6399	6408	6418	6428	6437	6447	6457	6466	6476	6486
62	6496	6505	6515	6525	6534	6544	6554	6563	6573	6583
63	6593	6602	6612	6622	6631	6641	6651	6660	6670	6680
64	6690	6699	6709	6719	6728	6738	6748	6757	6767	6777
65	6787	6796	6806	6816	6825	6835	6845	6854	6864	6874
0.66	6883	6892	6902	6912	6921	6931	6941	6950	6960	6970
67	6979	6988	6998	7008	7017	7027	7037	7046	7056	7066
68	7075	7084	7094	7103	7113	7122	7132	7141	7151	7160
69	7170	7179	7189	7198	7208	7217	7227	7236	7246	7255
70	7265	7274	7284	7293	7303	7312	7322	7331	7341	7350
0.71	7360	7369	7379	7388	7397	7407	7416	7426	7435	7445
72	7454	7463	7472	7482	7491	7501	7510	7520	7529	7539
73	7548	7557	7567	7576	7585	7595	7604	7614	7623	7633
74	7642	7651	7661	7670	7679	7689	7698	7708	7717	7727
75	7736	7745	7755	7764	7773	7783	7792	7802	7811	7821
0.76	7830	7839	7848	7858	7867	7876	7886	7895	7904	7914
77	7923	7932	7941	7951	7960	7969	7979	7988	7997	8007
78	8016	8025	8034	8044	8053	8062	8072	8081	8090	8100
79	8109	8118	8127	8137	8146	8155	8165	8174	8183	8193
80	8202	8211	8220	8229	8238	8248	8257	8266	8275	8284
0.81	8294	8303	8312	8321	8330	8340	8349	8358	8367	8376
82	8385	8394	8403	8412	8421	8431	8440	8449	8458	8467
83	8476	8485	8494	8503	8512	8522	8531	8540	8549	8558
84	8567	8576	8585	8594	8603	8613	8622	8631	8640	8649
85	8658	8667	8676	8685	8694	8704	8713	8722	8731	8740
0.86	8740	8758	8767	8776	8785	8795	8804	8813	8822	8831
87	8840	8849	8858	8867	8876	8886	8895	8904	8913	8922
88	8931	8940	8949	8958	8967	8977	8986	8995	9004	9013
89	9022	9031	9040	9049	9058	9067	9076	9085	9094	9103
90	9112	9121	9130	9139	9148	9157	9166	9175	9184	9193
0.91	9202	9211	9220	9229	9238	9247	9256	9265	9274	9283
92	9292	9300	9309	9318	9327	9336	9345	9354	9363	9372
93	9381	9389	9398	9407	9416	9425	9434	9443	9452	9461
94	9470	9478	9487	9496	9505	9514	9522	9531	9540	9549
95	9558	9566	9575	9584	9593	9602	9610	9619	9628	9637
.96	9646	9654	9663	9672	9681	9690	9698	9707	9716	9725
97	9734	9743	9752	9760	9769	9778	9787	9796	9805	9814
98	9823	9832	9841	9849	9858	9867	9876	9885	9894	9903
99	9912	9920	9929	9938	9947	9956	9964	9973	9982	0.9991
1.00	1.000	-	-	-	-	-	-	-	-	-

ε	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.00	0.000	0.0012	0.0023	0.0034	0.0045	0.0057	0.0068	0.0079	0.0090	0.0101
0.01	0.0112	124	135	146	157	169	180	191	202	213
2	224	236	247	258	269	281	292	303	314	325
3	336	348	359	370	381	392	403	414	425	436
4	447	459	470	481	492	503	514	525	536	547
5	558	570	571	592	603	614	625	636	647	658
0.06	669	681	692	703	714	725	736	747	758	769
7	780	791	802	813	824	835	846	857	868	879
8	890	901	912	923	934	945	956	967	978	989
9	0.1000	1011	1022	1033	1044	1055	1066	1077	1088	1099
10	1110	1121	1132	1143	1154	1165	1176	1187	1198	1209
0.11	1220	1231	1242	1253	1264	1275	1286	1297	1308	1319
12	1330	1341	1352	1363	1374	1385	1396	1407	1418	1429
13	1440	1451	1462	1473	1484	1495	1506	1517	1528	1539
14	1549	1560	1571	1582	1593	1604	1615	1626	1637	1648
15	1658	1669	1680	1691	1701	1712	1723	1734	1745	1756
0.16	1766	1777	1788	1799	1809	1820	1831	1842	1853	1864
17	1874	1885	1896	1907	1917	1928	1939	1950	1961	1972
18	1982	1993	2004	2015	2025	2036	2047	2058	2069	2079
19	2090	2100	2111	2122	2132	2143	2154	2164	2175	2186
20	2197	2207	2218	2229	2239	2250	2261	2271	2282	2293
0.21	2304	2314	2325	2335	2346	2357	2367	2378	2388	2399
22	2410	2420	2431	2441	2452	2463	2473	2484	2494	2505
23	2516	2526	2537	2547	2558	2569	2579	2590	2600	2611
24	2622	2632	2643	2653	2664	2675	2685	2696	2706	2717
25	2728	2738	2749	2759	2770	2781	2791	2802	2812	2823
0.26	2834	2844	2855	2865	2876	2887	2897	2908	2918	2929
27	2940	2950	2961	2971	2982	2992	3003	3013	3024	3034
28	3045	3055	3066	3076	3087	3097	3108	3118	3129	3139
29	3150	3160	3170	3181	3191	3202	3212	3223	3233	3244
30	3254	3264	3274	3285	3295	3306	3316	3327	3337	3348
0.31	3358	3368	3378	3389	3399	3410	3420	3431	3441	3452
32	3462	3472	3482	3493	3503	3514	3524	3535	3545	3556
33	3566	3577	3587	3597	3608	3618	3628	3639	3649	3659
34	3669	3680	3690	3700	3711	3721	3731	3742	3752	3762
35	3772	3783	3793	3803	3814	3824	3834	3845	3855	3865
0.36	3875	3886	3896	3906	3917	3927	3937	3948	3958	3968
37	3978	3989	3999	4009	4020	4030	4040	4051	4061	4071
38	4081	4092	4102	4112	4122	4132	4143	4153	4163	4173
39	4183	4194	4204	4214	4224	4234	4245	4255	4265	4275
40	4285	4296	4306	4316	4326	4336	4347	4357	4367	4377
0.41	4387	4398	4408	4418	4428	4438	4449	4459	4469	4479
42	4489	4500	4510	4520	4530	4540	4550	4560	4570	4580
43	4590	4601	4611	4621	4631	4641	4651	4661	4671	4681
44	4691	4702	4712	4722	4732	4742	4752	4762	4772	4782
45	4792	4803	4813	4823	4833	4843	4853	4863	4873	4883
0.46	4893	4904	4914	4924	4934	4944	4954	4964	4974	4984
47	4994	5005	5015	5025	5035	5045	5055	5065	5075	5085
48	5095	5105	5115	5125	5135	5145	5155	5165	5175	5185
49	5195	5205	5215	5225	5235	5245	5255	5265	5275	5285
50	5295	5305	5315	5325	5335	5345	5355	5365	5375	5385

4	447	459	470	481	492	503	514	525	536	547
5	558	570	571	592	603	614	625	636	647	658
0.06	669	681	692	703	714	725	736	747	758	769
7	780	791	802	813	824	835	846	857	868	879
8	890	901	912	923	934	945	956	967	978	989
9	0.1000	1011	1022	1033	1044	1055	1066	1077	1088	1099
10	1110	1121	1132	1143	1154	1165	1176	1187	1198	1209
0.11	1220	1231	1242	1253	1264	1275	1286	1297	1308	1319
12	1330	[illegible]11	1352	1363	1374	1385	1396	1407	1418	1429
13	1440	1451	1462	1473	1484	1495	1506	1517	1528	1539
14	1549	1560	1571	1582	1593	1604	1615	1626	1637	1648
15	1658	1669	1680	1691	1701	1712	1723	1734	1745	1756
0.16	1766	1777	1788	1799	1809	1820	1831	1842	1853	1864
17	1874	1885	1896	1907	1917	1928	1939	1950	1961	1972
18	1982	1993	2004	2015	2025	2036	2047	2058	2069	2079
19	2090	2100	2111	2122	2132	2143	2154	2164	2175	2186
20	2197	2207	2218	2229	2239	2250	2261	2271	2282	2293
0.21	2304	2314	2325	2335	2346	2357	2367	2378	2388	2399
22	2410	2420	2431	2441	2452	24[illegible]	2473	2484	2494	2505
23	2516	2526	2537	2547	2558	2[illegible]	2579	2590	2600	2611
24	2622	2632	2643	2653	2664	2675	2685	2696	2706	2717
25	2728	2738	2749	2759	2770	2781	2791	2802	2812	2823
0.26	2834	2844	2855	2865	2876	2887	2897	2908	2918	2929
27	2940	2950	2961	2971	2982	2992	3003	3013	3024	3034
28	3045	3055	3066	3076	3087	3097	3108	3118	3129	3139
29	3150	3160	3170	3181	3191	3202	3212	3223	3233	3244
30	3254	3264	3274	3285	3295	3306	3316	3327	3337	3348
0.31	3358	3368	3378	3389	3399	3410	3420	3431	3441	3452
32	3462	3472	3482	3493	3503	3514	3524	3535	3545	3556
33	3566	3577	3587	3597	3608	3618	3628	3639	3649	3659
34	3669	3680	3690	3700	3711	3721	3731	3742	3752	3762
35	3772	3783	3793	3803	3814	3824	3834	3845	3855	3865
0.36	3875	3886	3896	3906	3917	3927	3937	3948	3958	3968
37	3978	3989	3999	4009	4020	4030	4040	4051	4061	4071
38	4081	4092	4102	4112	4122	4132	4143	4153	4163	4173
39	4183	4194	4204	4214	4224	4234	4245	4255	4265	4275
40	4285	4296	4306	4316	4326	4336	4347	4357	4367	4377
0.41	4387	4398	4408	4418	4428	4438	4449	4459	4469	4479
42	4489	4500	4510	4520	4530	4540	4550	4560	4570	4580
43	4590	4601	4611	4621	4631	4641	4651	4661	4671	4681
44	4691	4702	4712	4722	4732	4742	4752	4762	4772	4782
45	4792	4803	4813	4823	4833	4843	4853	4863	4873	4883
0.46	4893	4904	4914	4924	4934	4944	4954	4964	4974	4984
47	4994	5005	5015	5025	5035	5045	5055	5065	5075	5085
48	5095	5105	5115	5125	5135	5145	5155	5165	5175	5185
49	5195	5205	5215	5225	5235	5245	5255	5265	5275	5285
50	5295	5305	5315	5325	5335	5345	5355	5365	5375	5385

0.51	0,5394	0.5404	0.5414	0.5424	0.5434	0.5444	0.5454	0.5464	0.5474	0.5484
52	5493	5503	5013	5523	5533	5543	5553	5563	5573	5583
53	5592	5602	5612	5622	5632	5642	5652	5662	5672	5682
54	5691	5701	5711	5721	5731	5741	5751	5761	5771	5781
55	5790	5800	5810	5820	5830	5840	5849	5859	5869	5879
0.56	5888	5898	5908	5918	5928	5938	5947	5957	5967	5977
57	5986	5996	6006	6016	6026	6036	6045	6055	6065	6075
58	6084	6094	6104	6114	6124	6134	6143	6153	6163	6173
59	6182	6192	6202	6212	6221	6231	6241	6250	6260	6270
60	6279	6289	6299	6309	6318	6328	6338	6347	6357	6367
0,61	6376	6386	6396	6406	6415	6425	6435	6444	6454	6464
62	6473	6483	6493	6503	6512	6522	6532	6541	6551	6561
63	6570	6580	6590	6599	6609	6618	6628	6637	6647	6657
64	6666	6676	6686	6695	6705	6714	6724	6733	6743	6753
65	6762	6772	6782	6791	6801	6810	6820	6829	6839	6849
0.66	6858	6868	6878	6887	6897	6906	6916	6925	6935	6945
67	6954	6964	6974	6983	6993	7002	7012	7021	7031	7041
68	7050	7060	7069	7079	7088	7098	7107	7117	7126	7136
69	7145	7155	7164	7174	7183	7193	7202	7212	7221	7231
70	7240	7250	7259	7269	7278	7288	7297	7307	7316	7326
0.71	7335	7344	7354	7363	7373	7382	7392	7401	7411	7420
72	7429	7438	7448	7457	7467	7476	7486	7495	7505	7514
73	7523	7582	7542	7551	7561	7570	7580	7589	7599	7608
74	7617	7626	7636	7645	7755	7664	7674	7683	7693	7702
75	7711	7721	7730	7740	7749	7758	7767	7777	7786	7796
0.76	7804	7814	7823	7832	7842	7851	7860	7870	7879	7888
77	7897	7907	7916	7925	7935	7944	7953	7963	7972	7981
78	7990	8000	8009	8018	8028	8037	8046	8056	8065	8074
79	8083	8093	8102	8118	8121	8130	8139	8149	8158	8167
80	8176	8186	8195	8204	8214	8223	8232	8242	8251	8280
0.81	8269	8279	8288	8297	8307	8316	8325	8835	8344	8353
82	8362	8372	8381	8390	8400	8409	8418	8428	8437	8446
83	8455	8465	8474	8483	8493	8502	8511	8521	8530	8539
84	8548	8558	8567	8576	8585	8594	8604	8613	8622	8631
85	8640	8650	8659	8668	8677	8686	8696	8705	8714	8723
0.86	8732	8742	8751	8760	8769	8778	8788	8797	8806	8815
87	8824	8834	8843	8852	8861	8870	8880	8889	8898	8907
88	8916	8926	8935	8944	8953	8962	8972	8981	8990	8999
89	9008	9017	9027	9036	9045	9054	9064	9073	9082	9091
90	9100	9109	9118	9127	9136	9146	9155	9164	9173	9182
0.91	9191	9200	9209	9218	9228	9237	9246	9255	9264	9273
92	9282	9291	9300	9310	9319	9328	9337	9346	9355	9364
93	9373	9382	9392	9401	9410	9419	9428	9437	9446	9455
94	9464	9473	9482	9491	9500	9509	9518	9527	9536	9545
95	9554	9563	9572	9581	9590	9599	9608	9617	9626	9635
0.96	9644	9653	9662	9671	9680	9689	9698	9707	9716	9725
97	9734	9743	9752	9761	9770	9779	9788	9797	9806	9814
98	9823	9832	9841	9850	9859	9868	9877	9886	9895	9904
99	9912	9921	9930	9939	9948	9957	9966	9975	9984	9992
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0.00	0	0.0012	0.0023	0.0034	0.0045	0.0057	0.0068	0.0079	0.0090	0.0101
0.01	0.0112	123	134	145	157	168	179	190	201	212
2	223	234	245	256	267	278	289	300	311	322
3	333	344	355	366	377	388	399	410	421	432
4	443	454	465	476	487	498	509	520	531	542
0.05	553	564	575	586	597	608	619	630	641	652
0.06	663	674	685	695	706	717	728	739	750	761
7	772	783	794	804	815	826	837	848	859	870
8	881	892	903	913	924	935	946	957	968	979
9	990	1001	1012	1022	1033	1044	1055	1066	1077	0.1088
0.10	0.1099	1110	1121	1131	1142	1153	1164	1175	1186	1197
0.11	1208	1219	1230	1240	1251	1262	1273	1284	1295	1305
12	1316	1327	1338	1348	1359	1370	1381	1392	1403	1413
13	1424	1435	1446	1456	1467	1478	1489	1500	1511	1521
14	1532	1543	1554	1564	1575	1586	1597	1608	1618	1529
15	1640	1650	1661	1672	1682	1693	1704	1715	1725	1736
0.16	1747	1757	1768	1779	1789	1800	1811	1822	1832	1843
17	1854	1864	1875	1886	1896	1907	1918	1929	1939	1950
18	1961	1971	1982	1993	2003	2014	2025	2036	2046	2057
19	2068	2078	2089	2100	2110	2121	2131	2142	2152	2163
20	2174	2184	2195	2206	2216	2227	2238	2249	2259	2270
0.21	2280	2290	2301	2312	2322	2333	2344	2355	2365	2376
22	2386	2396	2407	2418	2428	2439	2450	2461	2471	2442
23	2492	2503	2513	2524	2534	2545	2555	2566	2576	2587
24	2597	2608	2618	2629	2639	2650	2660	2671	2681	2692
25	2702	2713	2723	2734	2744	2755	2765	2776	2786	2797
0.26	2807	2818	2828	2839	2849	2860	2870	2881	2891	2902
27	2912	2923	2933	2944	2954	2964	2975	2985	2996	3006
28	3016	3027	3037	3048	3058	3068	3079	3089	3100	3110
29	3120	3131	3141	3152	3162	3172	3183	3193	3204	3214
30	3224	3235	3245	3256	3266	3276	3287	3297	3308	3318
0.31	3328	3339	3349	3360	3370	3380	3391	3401	3412	3422
32	3432	3443	3453	3464	3474	3484	3495	3505	3516	3526
33	3536	3547	3557	3567	3578	3588	3598	3609	3619	3629
34	3639	3650	3660	3670	3681	3691	3701	3712	3722	3732
35	3742	3753	3763	3773	3784	3794	3804	3815	3825	3835
0.36	3845	3856	3866	3876	3887	3897	3907	3918	3928	3938
37	3948	3959	3969	3979	3990	4000	4010	4021	4031	4041
38	4051	4062	4072	4082	4093	4103	4113	4124	4134	4144
39	4154	4165	4175	4185	4195	4205	4216	4226	4236	4246
40	4256	4267	4277	4287	4297	4307	4318	4328	4338	4348
0.41	4358	4369	4379	4389	4399	4409	4420	4430	4440	4450
42	4460	4470	4480	4490	4500	4511	4521	4531	4541	4551
43	4561	4571	4581	4591	4601	4612	4622	4632	4642	4652
44	4662	4672	4682	4692	4702	4713	4723	4733	4743	4753
45	4763	4773	4783	4793	4803	4813	4823	4833	4843	4853
.46	4863	4874	4884	4894	4904	4914	4924	4934	4944	4954
47	4964	4974	4984	4994	5004	5014	5024	5034	5044	5054
48	5064	5075	5085	5095	5105	5115	5125	5135	5145	5155
49	5165	5175	5185	5195	5205	5215	5225	5235	5245	5255
0.50	5265	5275	5285	5295	5305	5315	5325	5335	5345	5355

0.51	0.5365	0.5375	0.5385	0.5395	0.5405	0.5415	0.5425	0.5435	0.5445	0.5455
52	5465	5474	5484	5494	5504	5514	5524	5534	5544	5554
53	5564	5574	5583	5593	5603	5613	5623	5633	5643	5653
54	5663	5673	5683	5693	5702	5712	5722	5732	5742	5752
55	5762	5772	5782	5792	5802	5812	5821	5831	5841	5851
0.56	5861	5871	5881	5891	5901	5911	5921	5930	5940	5950
57	5960	5970	5980	5990	6000	6009	6019	6029	6039	6049
58	6058	6068	6078	6088	6097	6107	6117	6127	6137	6146
59	6156	6166	6176	6185	6195	6205	6215	6225	6234	6244
60	6254	6264	6273	6283	6293	6302	6312	6322	6331	6341
0.61	6351	6361	6370	6380	6390	6399	6409	6419	6428	6438
62	6448	6458	6467	6477	6487	6496	6506	6516	6525	6535
63	6545	6555	6564	6574	6584	6593	6603	6613	6622	6632
64	6642	6652	6661	6671	6681	6690	6700	6710	6719	6729
65	6739	6748	6758	6767	6777	6787	6796	6806	6815	6825
0.66	6835	6844	6854	6863	6873	6883	6892	6908	6911	6921
67	6931	6940	6950	6959	6969	6979	6988	6998	7007	7017
68	7027	7036	7046	7055	7065	7075	7084	7094	7103	7113
69	7123	7132	7142	7151	7161	7170	7180	7189	7199	7208
70	7218	7227	7237	7246	7256	7265	7275	7284	7294	7303
0.71	7313	7322	7332	7341	7351	7360	7370	7379	7389	7398
72	7408	7417	7427	7436	7446	7455	7465	7474	7484	7493
73	7503	7514	7512	7531	7541	7550	7560	7569	7579	7588
74	7598	7607	7617	7626	7636	7645	7655	7664	7674	7683
75	7693	7702	7712	7721	7731	7740	7750	7759	7769	7778
0.76	7788	7797	7807	7816	7826	7835	7845	7854	7864	7873
77	7883	7892	7902	7911	7920	7929	7939	7948	7958	7967
78	7977	7986	7996	8005	8014	8023	8033	8042	8052	8061
79	8071	8080	8090	8099	8108	8117	8127	8136	8146	8155
80	8165	8174	8184	8193	8202	8211	8221	8230	8240	8249
0.81	8259	8268	8278	8287	8296	8305	8315	8324	8334	8343
82	8353	8362	8372	8381	8390	8400	8409	8418	8428	8437
83	8446	8455	8465	8474	8483	8493	8502	8511	8521	8530
84	8539	8548	8558	8567	8576	8586	8595	8604	8614	8623
85	8632	8641	8651	8660	8669	8679	8688	8697	8707	8716
0.86	8725	8735	8744	8753	8762	8771	8781	8790	8799	8808
87	8817	8827	8836	8845	8854	8863	8873	8882	8891	8900
88	8909	8919	8928	8937	8946	8955	8965	8974	8983	8992
89	9001	9011	9020	9029	9038	9047	9057	9066	9075	9084
90	9093	9103	9112	9121	9130	9139	9149	9158	9167	9176
0.91	9185	9195	9204	9213	9222	9231	9240	9249	9258	9267
92	9276	9286	9295	9304	9313	9322	9331	9340	9349	9358
93	9367	9377	9386	9395	9404	9413	9422	9431	9440	9449
94	9458	9468	9477	9486	9495	9504	9513	9522	9531	9540
95	9549	9559	9568	9577	9586	9595	9604	9613	9622	9631
96	9640	9649	9658	9667	9676	9685	9694	9703	9712	9721
97	9730	9739	9748	9757	9766	9775	9784	9793	9802	9811
98	9820	9829	9838	9847	9856	9865	9874	9883	9892	9901
99	9910	9919	9928	9937	9946	9955	9964	9973	9982	0.9991
1.00	1,000	-	-	-	-	-	-	-	-	-

0.00	0.0000	0.0011	0.00[illegible]	0.0033	0.0044	0.0055	0.0066	0.0077	0.0088	0.0099
0.01	0.0110	121	132	143	154	165	175	186	197	208
2	219	230	241	252	263	274	284	295	306	317
3	328	339	350	361	372	383	393	404	415	426
4	437	448	459	470	481	492	502	513	524	535
5	546	557	568	579	590	601	611	622	633	644
0.06	655	666	677	688	699	710	720	731	742	753
7	764	775	796	796	807	818	829	840	850	861
8	872	883	894	904	915	926	937	948	958	969
9	980	990	0.100	1012	1022	1033	1044	1055	1065	1076
0.10	0.1087	1097	1108	1119	1129	1140	1151	1162	1172	1183
0.11	1194	1204	1215	1226	1236	1247	1258	1269	1279	1290
12	1301	1311	1322	1333	1343	1354	1365	1376	1386	1397
13	1408	1418	1429	1440	1450	1461	1472	1483	1493	1504
14	1515	1525	1536	1547	1557	1568	1579	1590	1600	1611
15	1622	1632	1643	1654	1664	1675	1686	1697	1707	1718
0.16	1729	1739	1750	1761	1771	1782	1792	1803	1814	1825
17	1835	1845	1856	1867	1877	1888	1898	1909	1920	1931
18	1941	1952	1962	1973	1983	1994	2004	2015	2026	2036
19	2047	2058	2068	2079	2089	2100	2110	2121	2132	2142
20	2153	2163	2174	2185	2195	2206	2216	2227	2238	2248
0.21	2259	2270	2280	2291	2301	2312	2322	2333	2343	2354
22	2364	2375	2385	2396	2406	2417	2428	2438	2448	2459
23	2469	2480	2490	2501	2511	2522	2532	2543	2553	2564
24	2574	2584	2595	2606	2616	2627	2637	2648	2658	2669
25	2679	2690	2700	2711	2721	2732	2742	2753	2763	2774
0.26	2784	2794	2804	2815	2825	2836	2846	2857	2867	2877
27	2888	2898	2908	2919	2929	2940	2950	2961	2971	2981
28	2992	3002	3012	3023	3033	3044	3054	3065	3075	3085
29	3096	3106	3116	3127	3137	3148	3158	3169	3179	3189
30	3200	3210	3220	3231	3241	3252	3262	3273	3283	3293
0.31	3304	3314	3324	3335	3345	3355	3366	3376	3386	3397
32	3407	3417	3427	3438	3448	3458	3469	3479	3489	3500
33	3510	3520	3530	3541	3551	3561	3572	3582	3592	3603
34	3613	3623	3633	3644	3654	3664	3675	3685	3695	3706
35	3716	3726	3736	3747	3757	3767	3778	3788	3798	3809
0.36	3819	3830	3840	3850	3860	3870	3881	3891	3901	3911
37	3921	3932	3942	3952	3962	3972	3983	3993	4003	4013
38	4023	4034	4044	4054	4064	4074	4085	4095	4105	4115
39	4125	4136	4146	4156	4166	4176	4187	4197	4207	4217
40	4227	4238	4248	4258	4268	4278	4289	4299	4309	4319
0.41	4329	4340	4350	4360	4370	4380	4390	4400	4410	4420
42	4430	4441	4451	4461	4471	4481	4491	4501	4511	4521
43	4531	4542	4552	4562	4572	4582	4592	4602	4612	4622
44	4632	4643	4653	4663	4673	4683	4693	4703	4713	4723
45	4733	4744	4754	4764	4774	4784	4794	4804	4814	4824
0.46	4834	4844	4854	4864	4874	4884	4894	4904	4914	4924
47	4934	4944	4954	4964	4974	4984	4994	5004	5014	5024
48	5034	5045	5055	5065	5075	4085	5095	5105	5115	5125
49	5135	5145	5155	5165	5175	5185	5195	5205	5215	5225
0.50	5235	5245	5255	5265	5275	5285	5295	5305	5315	5325

0.51	0.5335	0.5345	0.5355	0.5365	0.5375	0.5385	0.5395	0.5405	0.5415	0.5425
52	5434	5444	5454	5464	5474	5484	5494	5504	5514	5524
53	5533	5543	5553	5563	5573	5583	5593	5603	5613	5623
54	5632	5642	5652	5662	5672	5682	5692	5702	5712	5722
55	5731	5741	5751	5761	5771	5781	5791	5801	5811	5821
0.56	5830	5840	5850	5860	5870	5880	5890	5900	5910	5920
57	5929	5939	5949	5959	5969	5978	5988	5998	6008	6018
58	6027	6037	6047	6057	6067	6076	6086	6096	6106	6116
59	6125	6135	6145	6155	6165	6174	6184	6194	6204	6214
60	6223	6233	6243	6253	6263	6272	6282	6292	6302	6312
0.61	6321	6331	6341	6351	6361	6370	6380	6390	6400	6410
62	6419	6429	6439	6449	6459	6468	6478	6488	6498	6508
63	6517	6527	6537	6546	6556	6566	6575	6585	6595	6605
64	6614	6624	6634	6643	6653	6663	6672	6682	6692	6702
65	6711	6721	6731	6740	6750	6760	6769	6779	6789	6799
0.66	6808	6818	6828	6837	6847	6857	6866	6876	6886	6896
67	6905	6915	6925	6934	6944	6954	6963	6973	6983	6993
68	7002	7012	7022	7031	7041	7051	7060	7070	7080	7090
69	7099	7109	7119	7128	7138	7147	7157	7167	7176	7186
70	7195	7205	7215	7224	7234	7243	7253	7263	7272	7282
0.71	7291	7301	7311	7320	7330	7339	7349	7359	7368	7378
72	7387	7397	7406	7416	7425	7435	7444	7454	7463	7473
73	7482	7492	7501	7511	7520	7530	7539	7549	7558	7568
74	7577	7587	7596	7606	7615	7625	7634	7644	7653	7663
75	7672	7682	7691	7701	7710	7720	7729	7739	7748	7758
0.76	7767	7777	7786	7796	7805	7815	7824	7834	7843	7853
77	7862	7872	7881	7891	7900	7910	7919	7929	7938	7948
78	7957	7967	7976	7986	7995	8005	8014	8024	8033	8043
79	8052	8062	8071	8081	8090	8100	8109	8119	8128	8138
80	8147	8157	8166	8176	8185	8195	8204	8214	8223	8233
0.81	8242	8252	8261	8271	8280	8289	8299	8308	8318	8327
82	8336	8346	8355	8365	8374	8383	8393	8402	8412	8421
83	8430	8440	8449	8458	8468	8477	8486	8496	8505	8514
84	8523	8533	8542	8551	8561	8570	8579	8589	8598	8607
85	8616	8626	8635	8644	8654	8663	8672	8682	8691	8700
0.86	8709	8719	8728	8737	8747	8756	8765	8775	8784	8793
87	8802	8812	8821	8830	8840	8849	8858	8868	8877	8886
88	8895	8905	8914	8923	8933	8942	8951	8961	8970	8979
89	8988	8998	9007	9016	9026	9035	9044	9054	9063	9072
90	9081	9091	9100	9109	9119	9128	9137	9147	9156	9165
0.91	9174	9184	9193	9202	9212	9221	9230	9240	9249	9258
92	9267	9277	9296	9295	9304	9313	9323	9332	9341	9350
93	9359	9369	9378	9387	9396	9405	9415	9424	9433	9442
94	9451	9461	9470	9479	9488	9497	9507	9516	9525	9534
95	9543	9553	9562	9571	9580	9589	9599	9608	9617	9625
96	9635	9645	9654	9663	9672	9681	9691	9700	9709	9718
97	9727	9737	9746	9755	9764	9773	9782	9791	9800	9809
98	9818	9828	9837	9846	9855	9864	9873	9882	9891	9900
99	9909	9919	9928	9937	9946	9955	9964	9973	9982	9991
1.00	1.000	-	-	-	-	-	-	-	-	-

0.00	0	0.0011	0.0022	0.0033	0.0044	0.0055	0.0065	0.0076	0.0087	0.0098
0.01	0.0109	120	131	142	153	164	175	185	196	0.0207
2	218	229	240	251	262	273	283	294	305	316
3	326	337	348	359	370	381	391	402	413	424
4	434	445	456	467	478	489	499	510	521	532
5	542	553	564	575	586	597	607	618	629	640
0.06	650	661	672	683	694	705	715	726	737	748
7	758	769	780	791	801	812	823	834	844	855
8	865	876	886	897	908	919	929	940	950	961
9	971	982	992	0.1003	1014	1025	1035	1046	1056	1067
0.10	0.1077	1088	1098	1109	1120	1131	1141	1152	1162	1173
0.11	1183	1194	1205	1216	1226	1237	1248	1258	1269	1280
12	1290	1301	1311	1322	1333	1343	1354	1364	1375	1386
13	1396	1407	1417	1428	1439	1449	1460	1470	1481	1492
14	1502	1513	1523	1534	1545	1555	1566	1576	1587	1598
15	1608	1619	1629	1640	1651	1661	1672	1682	1693	1703
0.16	1714	1725	1735	1746	1757	1767	1778	1788	1799	1810
17	1820	1831	1841	1852	1863	1873	1884	1894	1905	1916
18	1926	1937	1947	1958	1968	1979	1989	2000	2010	2021
19	2031	2042	2052	2063	2073	2084	2094	2105	2115	2126
20	2136	2147	2157	2168	2178	2189	2199	2210	2220	2231
0.21	2241	2252	2262	2273	2283	2294	2304	2315	2325	2336
22	2346	2357	2367	2378	2388	2399	2409	2420	2430	2441
23	2451	2462	2472	2483	2493	2504	2514	2525	2535	2546
24	2556	2566	2577	2587	2598	2608	2619	2629	2639	2650
25	2660	2670	2681	2691	2702	2712	2723	2733	2743	2754
0.26	2764	2774	2785	2795	2806	2816	2827	2837	2847	2858
27	2868	2878	2889	2899	2910	2920	2931	2941	2951	2962
28	2972	2982	2993	3003	3014	3024	3035	3045	3055	3066
29	3076	3086	3096	3107	3117	3127	3138	3149	3159	3169
30	3179	3189	3199	3210	3220	3230	3241	3251	3261	3271
0.31	3282	3292	3302	3313	3323	3333	3344	3354	3364	3374
32	3385	3395	3405	3416	3426	3436	3447	3457	3467	3477
33	3488	3498	3508	3519	3529	3539	3549	3559	3570	3580
34	3590	3600	3610	3621	3631	3641	3651	3661	3672	3682
35	3692	3702	3712	3723	3733	3743	3753	3763	3774	3784
0.36	3794	3804	3814	3825	3835	3845	3855	3865	3876	3886
37	3896	3906	3916	3927	3937	3947	3957	3967	3978	3988
38	3998	4008	4018	4029	4039	4049	4059	4069	4080	4090
39	4100	4110	4120	4131	4141	4151	4161	4171	4182	4192
40	4202	4212	4222	4232	4242	4252	4263	4273	4283	4293
0.41	4303	4313	4323	4333	4343	4353	4364	4374	4384	4394
42	4404	4414	4424	4434	4444	4454	4465	4475	4485	4495
43	4505	4515	4525	4535	4545	4555	4566	4576	4586	4596
44	4606	4616	4626	4636	4646	4656	4667	4677	4687	4697
45	4707	4717	4727	4737	4747	4757	4767	4777	4787	4797
0.46	4807	4817	4827	4837	4847	4857	4868	4878	4888	4898
47	4908	4918	4928	4938	4948	4958	4968	4978	4988	4998
48	5008	5018	5028	5038	5048	5058	5069	5079	5089	5099
49	5109	5119	5129	5139	5149	5159	5169	5179	5189	5199
0.50	5209	5219	5229	5239	5249	5259	5269	5279	5289	5299

0.51	0.5309	0.5318	0.5328	0.5338	0.5348	0.5358	0.5368	0.5378	0.5388	0.5398
52	5408	5418	5428	5438	5448	5458	5468	5478	5488	5498
53	5508	5517	5527	5537	5547	5557	5567	5577	5587	5597
54	5607	5616	5626	5636	5646	5656	5666	5676	5686	5696
55	5706	5715	5725	5735	5745	5755	5765	5775	5785	5795
0.56	5805	5814	5824	5834	5844	5854	5864	5874	5884	5894
57	5904	5913	5923	5933	5943	5953	5963	5973	5983	5993
58	6003	6012	6022	6032	6042	6052	6061	6071	6081	6091
59	6101	6110	6120	6130	6140	6150	6159	6169	6179	6189
60	6199	6208	6218	6228	6238	6248	6257	6267	6277	6287
0.61	6297	6306	6316	6326	6336	6346	6355	6365	6375	6385
62	6395	6404	6414	6424	6434	6444	6453	6463	6473	6483
63	6493	6502	6512	6522	6532	6542	6551	6561	6571	6581
64	6591	6600	6610	6620	6629	6639	6649	6658	6668	6678
65	6688	6697	6707	6717	6726	6736	6746	6755	6765	6775
0.66	6785	6794	6804	6814	6823	6833	6843	6852	6862	6872
67	6882	6891	6901	6911	6920	6930	6940	6949	6959	6969
68	6979	6988	6998	7008	7017	7027	7037	7046	7056	7066
69	7076	7085	7095	7105	7114	7124	7134	7143	7153	7163
70	7173	7181	7192	7201	7211	7220	7230	7240	7249	7259
0.71	7269	7278	7288	7297	7307	7317	7326	7336	7345	7355
72	7365	7374	7384	7393	7403	7413	7422	7432	7441	7451
73	7461	7470	7480	7489	7499	7509	7518	7528	7537	7547
74	7557	7566	7576	7585	7595	7605	7614	7624	7633	7643
75	7653	7662	7672	7681	7691	7701	7710	7720	7729	7739
0.76	7749	7758	7768	7777	7787	7797	7806	7816	7825	7835
77	7845	7854	7864	7873	7883	7893	7902	7912	7921	7931
78	7941	7950	7960	7969	7979	7988	7998	8007	8017	8026
79	8036	8045	8055	8064	8074	8083	8093	8102	8112	8121
80	8131	8140	8150	8159	8169	8178	8188	8197	8207	8216
0.81	8226	8235	8245	8254	8264	8273	8283	8292	8302	8311
82	8321	8330	8340	8349	8358	8367	8377	8386	8396	8405
83	8415	8424	8434	8443	8452	8461	8471	8480	8490	8499
84	8509	8518	8528	8537	8546	8555	8565	8574	8584	8593
85	8603	8612	8622	8631	8640	8649	8659	8668	8678	8687
0.86	8697	8706	8716	8725	8734	8743	8753	8762	8772	8781
87	8791	8800	8810	8819	8828	8837	8847	8856	8866	8875
88	8885	8894	8904	8913	8922	8931	8941	8950	8960	8969
89	8979	8988	8998	9007	9016	9025	9035	9044	9054	9063
90	9073	9082	9092	9101	9110	9119	9129	9138	9148	9157
0.91	9167	9176	9186	9195	9204	9213	9223	9232	9241	9250
92	9260	9269	9278	9288	9297	9306	9316	9325	9334	9343
93	9353	9362	9371	9381	9390	9399	9409	9418	9427	9436
94	9446	9455	9464	9474	9483	9492	9502	9511	9520	9529
95	9539	9548	9557	9567	9576	9585	9595	9604	9613	9622
96	9632	9641	9650	9659	9668	9678	9687	9696	9705	9714
97	9724	9733	9742	9751	9760	9770	9779	9788	9797	9806
98	9816	9825	9834	9843	9852	9862	9871	9880	9889	9898
99	9908	9917	9926	9935	9944	9954	9963	9972	9981	9991
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0.00	0	0.0011	0.0022	0.0033	0.0043	0.0054	0.0065	0.0075	0.0086	0.0097
0.01	0.0107	118	129	140	150	161	172	182	193	204
2	214	225	236	247	257	268	279	290	300	311
3	322	333	344	355	365	376	387	397	408	419
4	429	440	451	462	472	483	494	504	515	526
5	536	547	558	569	579	590	601	611	622	633
0.06	643	654	665	675	686	696	707	717	728	739
7	749	760	771	781	792	802	813	823	834	844
8	855	866	877	887	898	908	919	929	940	950
9	961	972	983	993	1004	1014	1025	1035	1046	1056
0.10	0.1067	1078	1089	1099	1110	1120	1131	1141	1152	1162
0.11	1173	1184	1194	1205	1215	1226	1236	1247	1257	1268
12	1278	1289	1300	1310	1321	1331	1342	1352	1363	1373
13	1384	1395	1406	1416	1427	1437	1448	1458	1469	1479
14	1490	1500	1511	1521	1532	1542	1553	1563	1574	1584
15	1595	1605	1616	1626	1637	1647	1658	1668	1679	1689
0.16	1700	1710	1721	1731	1742	1752	1763	1773	1784	1794
17	1805	1815	1826	1836	1847	1857	1868	1878	1889	1899
18	1910	1920	1931	1941	1952	1962	1973	1983	1994	2004
19	2015	2025	2035	2046	2056	2067	2077	2088	2098	2108
20	2119	2129	2139	2150	2160	2171	2181	2192	2202	2212
0.21	2223	2233	2243	2254	2264	2275	2285	2296	2306	2316
22	2327	2337	2347	2358	2368	2379	2389	2400	2410	2420
23	2431	2441	2451	2462	2472	2483	2493	2504	2514	2524
24	2535	2545	2555	2566	2576	2587	2597	2608	2618	2628
25	2639	2650	2660	2670	2681	2691	2701	2712	2722	2732
0.26	2742	2753	2763	2773	2784	2794	2804	2815	2825	2835
27	2845	2856	2866	2876	2887	2897	2907	2918	2928	2938
28	2948	2959	2969	2979	2990	3000	3010	3021	3031	3041
29	3051	3062	3072	3082	3093	3103	3113	3124	3134	3144
30	3154	3165	3175	3185	3196	3206	3216	3227	3237	3247
0.31	3257	3268	3278	3288	3299	3309	3319	3330	3340	3350
32	3360	3371	3381	3391	3401	3411	3422	3432	3442	3452
33	3462	3473	3483	3493	3503	3513	3524	3534	3544	3554
34	3564	3575	3585	3595	3605	3615	3626	3636	3646	3656
35	3666	3677	3687	3697	3707	3717	3728	3738	3748	3758
0.36	3768	3779	3789	3799	3809	3819	3830	3840	3850	3860
37	3870	3881	3891	3901	3911	3921	3932	3942	3952	3962
38	3972	3983	3993	4003	4013	4023	4034	4044	4054	4064
39	4074	4085	4095	4105	4115	4125	4136	4146	4156	4166
40	4176	4187	4197	4207	4217	4227	4237	4247	4257	4267
0.41	4277	4288	4298	4308	4318	4328	4338	4348	4358	4368
42	4378	4389	4399	4409	4419	4429	4439	4449	4459	4469
43	4479	4489	4499	4509	4519	4529	4539	4549	4559	4569
44	4579	4590	4600	4610	4620	4630	4640	4650	4660	4670
45	4680	4690	4700	4710	4720	4730	4740	4750	4760	4770
0.46	4781	4791	4801	4811	4821	4831	4841	4851	4861	4871
47	4881	4891	4901	4911	4921	4931	4941	4951	4961	4971
48	4981	4991	5001	5011	5021	5031	5041	5051	5061	5072
49	5082	5092	5102	5112	5122	5132	5142	5152	5162	5172
50	5182	5192	5202	5212	5222	5232	5242	5252	5262	5272

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52	5381	5391	5401	5411	5421	5431	5441	5451	5461	5471
53	5481	5490	5500	5510	5520	5530	5540	5550	5560	5570
54	5580	5589	5599	5609	5619	5629	5639	5649	5659	5669
55	5679	5688	5698	5708	5718	5728	5738	5748	5758	5768
0.56	5778	5787	5797	5807	5817	5827	5837	5847	5857	5867
57	5877	5886	5896	5906	5916	5926	5936	5946	5956	5966
58	5976	5985	5995	6005	6015	6025	6035	6045	6055	6065
59	6075	6084	6094	6104	6114	6124	6133	6143	6153	6163
60	6173	6182	6192	6202	6212	6222	6231	6241	6251	6261
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62	6369	6378	6388	6398	6408	6418	6427	6437	6447	6457
63	6467	6476	6486	6496	6506	6516	6525	6535	6445	6555
64	6565	6574	6584	6594	6604	6614	6623	6633	6643	6653
65	6663	6672	6682	6692	6702	6712	6721	6731	6741	6751
0.66	6761	6770	6780	6790	6800	6810	6819	6829	6839	6849
67	6859	6868	6878	6888	6897	6907	6917	6926	6936	6946
68	6956	6965	6975	6985	6994	7004	7014	7023	7033	7043
69	7053	7062	7072	7082	7091	7101	7111	7120	7130	7140
70	7150	7159	7169	7179	7188	7198	7208	7217	7227	7237
0.71	7247	7256	7266	7276	7285	7295	7305	7314	7324	7334
72	7344	7353	7363	7373	7382	7392	7402	7411	7421	7431
73	7441	7450	7460	7469	7479	7489	7498	7508	7517	7527
74	7537	7546	7556	7565	7575	7585	7594	7604	7613	7623
75	7633	7642	7652	7661	7671	7681	7690	7700	7709	7719
0.76	7729	7738	7748	7757	7767	7777	7786	7796	7805	7815
77	7825	7834	7844	7853	7863	7873	7882	7892	7901	7911
78	7921	7930	7940	7949	7959	7969	7978	7988	7997	8007
79	8017	8026	8036	8045	8055	8065	8074	8084	8093	8103
80	8113	8122	8132	8141	8151	8161	8170	8180	8189	8199
0.81	8209	8218	8228	8237	8247	8257	8266	8276	8285	8295
82	8305	8314	8324	8333	8343	8352	8362	8371	8381	8390
83	8400	8409	8419	8428	8438	8447	8457	8466	8476	8485
84	8495	8504	8514	8523	8533	8542	8552	8561	8571	8580
85	8590	8599	8609	8618	8628	8637	8647	8656	8666	8675
0.86	8685	8694	8704	8713	8723	8732	8742	8751	8761	8770
87	8780	8789	8799	8808	8818	8827	8837	8846	8856	8865
88	8875	8884	8894	8903	8913	8922	8932	8941	8951	8960
89	8970	8979	8989	8998	9007	9016	9026	9035	9045	9054
90	9064	9073	9083	9092	9101	9110	9120	9129	9139	9148
0.91	9158	9167	9177	9186	9195	9204	9214	9223	9233	9242
92	9252	9261	9271	9280	9289	9298	9308	9317	9327	9336
93	9346	9355	9365	9374	9383	9392	9402	9411	9421	9430
94	9440	9449	9459	9468	9477	9486	9496	9505	9515	9524
95	9534	9543	9553	9562	9571	9580	9590	9599	9609	9618
0.96	9628	9637	9647	9656	9665	9674	9684	9693	9702	9711
97	9721	9730	9740	9749	9758	9767	9777	9786	9795	9804
98	9814	9823	9833	9842	9851	9860	9869	9878	9888	9897
99	9907	9916	9926	9935	9944	9954	9963	9972	9982	9991
1.00	1.000	-	-	-	-	-	-	-	-	-

0.00	0	0.0011	0.0022	0.0032	0.0043	0.0054	0.0065	0.0075	0.0086	0.0096
0.01	0.0107	118	129	139	150	160	171	181	192	202
2	213	224	235	245	256	266	277	287	298	308
3	319	330	340	351	361	372	382	393	403	414
4	425	436	447	457	468	478	489	499	510	520
5	531	541	552	562	573	583	594	604	615	625
0.06	636	647	658	668	679	689	700	710	721	731
7	742	752	763	773	784	794	805	815	826	836
8	847	858	869	879	890	900	911	921	932	942
9	952	963	974	984	995	0.1005	1016	1026	1037	1047
0.10	0.1057	1067	1078	1088	1099	1109	1120	1130	1141	1151
0.11	1162	1172	1183	1193	1204	1214	1225	1235	1246	1256
12	1267	1277	1288	1298	1309	1319	1330	1340	1351	1361
13	1372	1382	1393	1403	1413	1424	1434	1445	1455	1466
14	1476	1486	1497	1507	1517	1528	1538	1549	1559	1570
15	1580	1590	1601	1611	1621	1632	1642	1653	1663	1674
0.16	1684	1694	1705	1715	1725	1736	1746	1757	1767	1778
17	1788	1798	1809	1819	1829	1840	1850	1861	1871	1882
18	1892	1902	1913	1923	1933	1944	1954	1965	1975	1986
19	1996	2006	2017	2027	2037	2048	2058	2069	2079	2090
20	2100	2110	2120	2131	2141	2151	2162	2172	2182	2193
0.21	2203	2213	2223	2234	2244	2254	2265	2275	2285	2296
22	2306	2316	2326	2337	2347	2357	2368	2378	2388	2399
23	2409	2419	2429	2440	2450	2460	2471	2483	2491	2502
24	2512	2522	2532	2543	2553	2563	2574	2584	2594	2605
25	2615	2625	2635	2646	2656	2666	2677	2687	2697	2708
0.26	2718	2728	2738	2749	2759	2769	2780	2790	2800	2811
27	2821	2831	2841	2852	2862	2873	2883	2893	2903	2914
28	2924	2934	2944	2955	2965	2975	2986	2996	3006	3017
29	3027	3037	3047	3058	3068	3078	3089	3099	3109	3120
30	3130	3140	3150	3160	3171	3181	3191	3201	3211	3222
0.31	3232	3242	3252	3262	3273	3283	3293	3303	3313	3324
32	3334	3344	3354	3364	3375	3385	3395	3405	3415	3426
33	3436	3446	3456	3466	3477	3487	3497	3507	3517	3528
34	3538	3548	3558	3568	3579	3589	3599	3609	3619	3630
35	3640	3650	3660	3670	3681	3691	3701	3711	3721	3732
0.36	3742	3752	3762	3772	3783	3793	3803	3813	3823	3834
37	3844	3854	3864	3874	3884	3895	3905	3915	3925	3935
38	3945	3955	3965	3975	3985	3996	4006	4016	4026	4036
39	4046	4056	4066	4076	4086	4097	4107	4117	4127	4137
40	4147	4157	4167	4177	4187	4198	4208	4218	4228	4238
0.41	4248	4253	4268	4278	4288	4299	4309	4319	4329	4339
42	4349	4359	4369	4279	4389	4400	4410	4420	4430	4440
43	4450	4460	4470	4480	4490	4501	4511	4521	4531	4541
44	4551	4561	4571	4581	4591	4602	4612	4622	4632	4642
45	4652	4662	4672	4682	4692	4703	4713	4723	4733	4743
0.46	4753	4763	4773	4783	4793	4803	4813	4823	4833	4843
47	4853	4864	4874	4884	4894	4904	4914	4924	4934	4944
48	4954	4964	4974	4984	4994	5004	5014	5024	5034	5044
49	5054	5064	5074	5084	5094	5104	5114	5124	5134	5144
50	5154	5164	5174	5184	5194	5204	5214	5224	5234	5244

0.51	0.5254	0.5264	0.5274	0.5284	0.5294	0.5304	0.5314	0.5324	0.5334	0.5344
52	5354	5364	5374	5384	5394	5404	5414	5424	5434	5444
53	5454	5464	5474	5484	5494	5504	5514	5524	5534	5544
54	5554	5564	5574	5584	5594	5604	5614	5624	5634	5644
55	5653	5663	5673	5683	5693	5703	5713	5723	5733	5743
0.56	5752	5762	5772	5782	5792	5802	5812	5822	5832	5842
57	5851	5861	5871	5881	5891	5901	5911	5921	5931	5941
58	5950	5960	5970	5980	5990	6000	6010	6020	6030	6040
59	6049	6059	6069	6079	6089	6098	6108	6118	6128	6138
60	6147	6157	6167	6177	6187	6196	6206	6216	6226	6236
0.61	6245	6255	6265	6275	6285	6294	6304	6314	6324	6334
62	6343	6353	6363	6373	6383	6392	6402	6412	6422	6432
63	6441	6451	6461	6471	6481	6490	6500	6510	6520	6530
64	6539	6549	6559	6569	6579	6588	6598	6608	6618	6628
65	6637	6647	6657	6667	6677	6686	6696	6706	6716	6726
0.66	6735	6745	6755	6765	6775	6784	6794	6804	6814	6824
67	6833	6843	6853	6863	6873	6882	6892	6902	6912	6922
68	6931	6941	6951	6961	6971	6980	6990	7000	7010	7020
69	7029	7039	7049	7059	7068	7078	7088	7097	7107	7117
70	7126	7136	7146	7156	7165	7175	7185	7194	7204	7214
0.71	7223	7233	7243	7253	7262	7272	7282	7291	7301	7311
72	7320	7330	7340	7350	7359	7369	7379	7388	7398	7408
73	7417	7427	7437	7447	7456	7466	7476	7485	7495	7505
74	7514	7524	7534	7544	7553	7563	7573	7582	7592	7602
75	7611	7621	7631	7641	7650	7660	7670	7679	7689	7699
0.76	7708	7718	7728	7738	7747	7757	7767	7776	7786	7796
77	7805	7815	7825	7835	7844	7854	7864	7873	7883	7893
78	7902	7912	7922	7932	7941	7951	7961	7970	7980	7990
79	7999	8009	8019	8029	8038	8048	8058	8067	8077	8087
80	8096	8106	8116	8126	8135	8145	8155	8164	8174	8184
0.81	8193	8203	8212	8222	8232	8241	8251	8260	8270	8280
82	8289	8299	8308	8318	8328	8337	8347	8356	8366	8376
83	8385	8395	8404	8414	8424	8433	8443	8452	8362	8472
84	8481	8491	8500	8510	8520	8529	8539	8548	8558	8568
85	8577	8587	8596	8606	8616	8625	8635	8644	8654	8664
0.86	8673	8683	8692	8702	8712	8721	8731	8740	8750	8760
87	8769	8779	8788	8798	8807	8817	8826	8836	8845	8855
88	8864	8874	8883	8893	8902	8912	8921	8931	8940	8950
89	8959	8969	8978	8988	8997	9007	9016	9026	9035	9045
90	9054	9064	9073	9083	9092	9102	9111	9121	9130	9140
0.91	9150	9160	9169	9179	9188	9198	9207	9217	9226	9236
92	9245	9255	9264	9274	9283	9293	9302	9312	9321	9331
93	9340	9350	9359	9369	9378	9388	9397	9407	9416	9426
94	9435	9445	9454	9464	9473	9483	9492	9502	9511	9521
95	9530	9540	9549	9559	9568	9577	9587	9596	9606	9615
0.96	9624	9634	9643	9653	9662	9671	9681	9690	9700	9709
97	9718	9728	9737	9747	9756	9865	9775	9784	9794	9803
98	9812	9822	9831	9841	9850	9859	9869	9878	9888	9897
99	9906	9916	9925	9935	9944	9953	9963	9972	9981	9991
1.00	1.000	–	–	–	–	–	–	–	–	–

0.00	0	0.0011	0.0022	0.0032	0.0043	0.0053	0.0064	0.0074	0.0085	0.0096
0.01	0.0106	117	127	138	148	159	169	180	190	0.0201
2	211	222	232	243	253	264	274	285	295	306
3	316	327	337	348	358	369	379	390	400	411
4	421	432	442	453	463	474	484	495	505	516
5	526	537	547	558	568	579	589	600	610	621
0.06	631	642	652	663	673	684	694	705	715	726
7	736	747	757	768	778	789	799	810	820	831
8	841	851	862	872	883	893	904	914	925	935
9	945	955	966	976	987	997	1008	1018	1029	1039
0.10	1049	1059	1070	1080	1091	1101	1112	1122	1133	1143
0.11	1153	1163	1173	1184	1195	1205	1216	1226	1237	1247
12	1257	1267	1278	1288	1299	1309	1320	1330	1341	1351
13	1361	1371	1382	1392	1403	1413	1424	1434	1445	1455
14	1465	1475	1486	1496	1507	1517	1528	1538	1549	1559
15	1569	1579	1590	1600	1610	1621	1631	1641	1652	1662
0.16	1672	1682	1693	1703	1713	1724	1734	1744	1755	1765
17	1775	1785	1796	1806	1816	1827	1837	1847	1858	1868
18	1878	1888	1899	1909	1919	1930	1940	1950	1961	1971
19	1981	1991	2002	2012	2022	2033	2043	2053	2064	2074
20	2084	2094	2105	2115	2125	2136	2146	2156	2167	2177
0.21	2187	2197	2208	2218	2228	2239	2249	2259	2270	2280
22	2290	2300	2311	2321	2331	2342	2352	2362	2373	2383
23	2393	2403	2414	2424	2434	2445	2455	2455	2476	2486
24	2496	2506	2517	2527	2537	2648	2558	2568	2579	2589
25	2599	2610	2620	2630	2640	2650	2661	2671	2581	2691
0.26	2701	2712	2722	2732	2742	2752	2763	2773	2783	2793
27	2803	2814	2824	2834	2844	2854	2865	2875	2885	2895
28	2905	2916	2926	2936	2946	2956	2967	2977	2987	2997
29	3007	3018	3028	3038	3048	3058	3069	3079	3089	3099
30	3109	3120	3130	3140	3150	3160	3171	3181	3191	3201
0.31	3211	3222	3232	3242	3252	3262	3273	3283	3293	3303
32	3313	3324	3334	3344	3354	3364	3375	3384	3395	3405
33	3415	3426	3436	3446	3456	3466	3477	3487	3497	3507
34	3517	3528	3538	3548	3558	3568	3579	3589	3599	3609
35	3619	3630	3640	3650	3660	3670	3681	3691	3701	3711
0.36	3721	3732	3742	3752	3762	3772	3782	3792	3802	3812
37	3822	3833	3843	3853	3863	3873	3883	3893	3903	3913
38	3923	3943	3944	3954	3964	3974	3984	3994	4004	4014
39	4024	4035	4045	4055	4065	4075	4085	4095	4105	4115
40	4125	4136	4146	4156	4166	4176	4186	4196	4206	4216
0.41	4226	4237	4247	4257	4267	4277	4287	4297	4307	4317
42	4327	4338	4348	4358	4368	4378	4388	4398	4408	4418
43	4428	4439	4449	4459	4469	4479	4489	4499	4509	4519
44	4529	4540	4550	4560	4570	4580	4590	4600	4610	4620
45	4630	4640	4650	4660	4670	4680	4690	4700	4710	4720
0.46	4730	4740	4750	4760	4770	4780	4790	4800	4810	4820
47	4830	4840	4850	4860	4870	4880	4890	4900	4910	4920
48	4931	4941	4951	4961	4971	4981	4991	5001	5011	5021
49	5031	5041	5051	5061	5071	5081	5091	5101	5111	5121
50	5131	5141	5151	5161	5171	5181	5191	5201	5211	5221

0.51	0.5231	0.5241	0.5251	0.5261	0.5271	0.5281	0.5291	0.5301	0.5311	0.5321
52	5331	5441	5351	5361	5371	5381	5391	5401	5411	5421
53	5431	5441	5451	5461	5471	5481	5491	5500	5510	5520
54	5530	5540	5550	5560	5570	5580	5590	5600	5610	5620
55	5630	5640	5650	5660	5670	5680	5690	5700	5710	5719
0.56	5729	5739	5749	5759	5769	5779	5789	5799	5809	5818
57	5828	5838	5848	5858	5868	5878	5888	5898	5908	5917
58	5927	5937	5947	5957	5967	5977	5987	5997	6007	6016
59	6026	6036	6046	6056	6066	6076	6086	6096	6106	6115
60	6125	6135	6145	6155	6165	6175	6185	6195	6205	6214
0.61	6224	6234	6244	6254	6264	6273	6283	6293	6303	6312
62	6322	6332	6342	6352	6362	6371	6381	6391	6401	6410
63	6420	6430	6440	6450	6460	6469	6479	6489	6499	6508
64	6518	6528	6538	6548	6558	6567	6577	6587	6597	6606
65	6616	6626	6636	6646	6656	6665	6675	6685	6695	6704
0.66	6714	6724	6734	6744	6754	6763	6773	6783	6793	6802
67	6812	6822	6832	6842	6852	6861	6871	6881	6891	6900
68	6910	6920	6930	6940	6950	6959	6969	6979	6989	6998
69	7008	7018	7028	7038	7048	7057	7067	7077	7087	7096
70	7106	7116	7126	7136	7146	7155	7165	7175	7185	7194
0.71	7204	7214	7224	7234	7244	7253	7263	7273	7283	7292
72	7302	7312	7322	7332	7342	7351	7361	7371	7381	7390
73	7400	7410	7420	7430	7440	7449	7459	7469	7479	7488
74	7498	7508	7518	7528	7538	7547	7557	7567	7577	7586
75	7596	7606	7616	7626	7635	7645	7655	7664	7674	7683
0.76	7693	7703	7713	7723	7732	7742	7752	7761	7771	7780
77	7790	7800	7810	7820	7829	7839	7849	7858	7868	7877
78	7887	7897	7907	7916	7926	7936	7945	7955	7965	7974
79	7984	7994	8004	8013	8023	8033	8042	8052	8062	8071
80	8081	8091	8101	8110	8120	8130	8139	8149	8159	8168
0.81	8178	8188	8198	8207	8217	8227	8236	8246	8256	8265
82	8275	8285	8295	8304	8314	8324	8333	8343	8353	8362
83	8372	8382	8392	8401	8411	8421	8430	8440	8450	8459
84	8469	8479	8489	8498	8508	8518	8527	8537	8547	8556
85	8566	8575	8585	8594	8604	8614	8623	8633	8643	8652
0.86	8662	8671	8681	8690	8700	8710	8719	8729	8739	8748
87	8758	8767	8777	8786	8796	8806	8815	8825	8835	8844
88	8854	8863	8873	8882	8892	8902	8911	8921	8931	8940
89	8950	8959	8969	8978	8988	8998	9007	9017	9027	9036
90	9046	9055	9065	9074	9084	9094	9103	9113	9123	9132
0.91	9142	9151	9161	9170	9180	9190	9199	9209	9219	9228
92	9238	9247	9257	9266	9276	9286	9295	9305	9315	9324
93	9334	9343	9253	9362	9372	9382	9391	9401	9411	9420
94	9430	9439	9449	9458	9468	9477	9487	9496	9506	9515
95	9525	9534	9544	9553	9563	9572	9582	9591	9601	9610
0.96	9620	9629	9639	9648	9658	9667	9677	9686	9696	9705
97	9715	9724	9734	9743	9753	9762	9772	9782	9791	9800
98	9810	9819	9829	9838	9848	9857	9867	9876	9886	9895
99	9905	9914	9924	9933	9943	9952	9962	9971	9981	0.9990
1.00	1.000	-	-	-	-	-	-	-	-	-

0.00	0	0.0011	0.0022	0.0032	0.0042	0.0053	0.0063	0.0073	0.0084	0.0094
0.01	0.0104	115	125	136	146	156	167	177	188	198
2	208	219	229	240	250	260	271	281	292	302
3	312	323	333	344	354	364	375	385	396	406
4	416	427	337	448	458	468	479	489	500	510
5	520	531	541	552	562	572	583	593	604	614
0.06	624	634	644	655	665	675	686	696	707	717
7	727	737	747	758	768	778	789	799	810	820
8	830	841	851	862	872	882	893	903	914	924
9	934	944	954	965	975	985	996	1006	1017	1027
0.10	0.1037	1047	1057	1068	1078	1088	1099	1109	1120	1130
0.11	1140	1151	1161	1172	1182	1192	1203	1213	1224	1234
12	1244	1254	1264	1275	1285	1295	1306	1316	1327	1337
13	1347	1357	1367	1378	1388	1398	1409	1419	1430	1440
14	1450	1460	1470	1481	1491	1501	1512	1522	1533	1543
15	1553	1563	1573	1584	1594	1604	1615	1625	1636	1646
0.16	1656	1666	1676	1686	1697	1707	1717	1727	1738	1748
17	1758	1768	1778	1788	1799	1809	1819	1829	1840	1850
18	1860	1871	1881	1891	1902	1912	1922	1932	1943	1954
19	1963	1974	1984	1994	2005	2015	2025	2035	2046	2057
20	2066	2076	2086	2096	2107	2117	2127	2137	2148	2158
0.21	2168	2178	2188	2198	2209	2219	2229	2239	2250	2260
22	2270	2280	2290	2300	2311	2321	2331	2341	2352	2362
23	2372	2382	2392	2402	2413	2423	2433	2443	2454	2464
24	2474	2484	2494	2504	2515	2525	2535	2545	2556	2566
25	2576	2586	2596	2606	2617	2627	2637	2647	2658	2668
0.26	2678	2688	2698	2708	2719	2729	2739	2749	2760	2770
27	2780	2790	280	2810	2821	2831	2841	2851	2862	2872
28	2882	2892	2902	2912	2923	2933	2943	2953	2964	2974
29	2984	2994	3004	3014	3025	3035	3045	3055	3066	3076
30	3086	3096	3106	3116	3127	3137	3147	3157	3168	3178
0.31	3187	3197	3207	3217	3228	3238	3248	3258	3268	3278
32	3288	3299	3309	3319	3330	3340	3350	3360	3370	3380
33	3390	3400	3410	3420	3431	3441	3451	3461	3471	3481
34	3491	3502	3512	3522	3532	3543	3553	3563	3573	3583
35	3593	3603	3613	3623	3633	3644	3654	3664	3674	3684
0.36	3694	3704	3714	3724	3734	3745	3755	3765	3775	3785
37	3795	3805	3815	3825	3835	3846	3856	3866	3876	3886
38	3896	3906	3916	3926	3936	3947	3957	3967	3977	3987
39	3997	4007	4017	4027	4037	4048	4058	4068	4078	4088
40	4098	4108	4118	4128	4138	4149	4159	4169	4179	4189
0.41	4199	4209	4219	4229	4239	4250	4260	4270	4280	4290
42	4300	4310	4320	4330	4340	4350	4360	4370	4380	4390
43	4400	4410	4420	4430	4440	4450	4460	4470	4480	4490
44	4500	4511	4521	4531	4541	4551	4561	4571	4581	4591
45	4601	4611	4621	4631	4641	4651	4661	4671	4681	4691
0.46	4701	4711	4721	4731	4741	4751	4761	4771	4781	4791
47	4802	4812	4822	4832	4842	4852	4862	4872	4882	4892
48	4902	4912	4922	4932	4942	4952	4962	4972	4982	4992
49	5002	5012	5022	5032	5042	5052	5062	5072	5082	5092
50	5102	5112	5122	5132	5142	5152	5162	5172	5182	5192

0.51	0.5202	0.5212	0.5222	0.5232	0.5242	0.5252	0.5262	0.5272	0.5282	0.5292
52	5302	5311	5321	5331	5341	5351	5361	5371	5381	5391
53	5401	5411	5421	5431	5441	5451	5461	5171	5481	5491
54	5501	5510	5520	5530	5540	5550	5560	5570	5580	5590
55	5600	5610	5620	5630	5640	5650	5660	5670	5680	5690
0.56	5700	5709	5719	5729	5739	5749	5759	5769	5779	5789
57	5799	5809	5819	5829	5839	5849	5859	5869	5879	5889
58	5899	5908	5918	5928	5938	5948	5958	5968	5978	5988
59	5998	6007	6017	6027	6037	6047	6057	6067	6077	6087
60	6097	6106	6116	6126	6136	6146	6156	6166	6176	6186
0.61	6196	6205	6215	6225	6235	6245	6255	6265	6275	6285
62	6295	6304	6314	6324	6334	6344	6354	6364	6374	6384
63	6394	6403	6413	6423	6433	6443	6453	6463	6473	6483
64	6493	6502	6512	6522	6532	6542	6552	6562	6572	6582
65	6592	6601	6611	6621	6631	6640	6650	6660	6670	6680
0.66	6690	6700	6709	6719	6729	6739	6749	6759	6769	6779
67	6789	6799	6808	6818	6828	6838	6848	6858	6868	6878
68	6888	6898	6907	6917	6927	6937	6946	6956	6966	6976
69	6986	6996	7006	7015	7025	7035	7045	7055	7065	7075
70	7085	7095	7104	7114	7124	7134	7143	7153	7163	7173
0.71	7183	7193	7202	7212	7222	7232	7241	7251	7261	7271
72	7281	7291	7300	7310	7320	7330	7339	7349	7359	7369
73	7379	7389	7398	7408	7418	7428	7437	7447	7457	7467
74	7477	7487	7496	7506	7516	7526	7535	7545	7555	7565
75	7575	7585	7594	7604	7614	7624	7633	7643	7653	7663
0.76	7673	7683	7692	7702	7712	7722	7731	7741	7751	7761
77	7771	7781	7790	7800	7810	7820	7829	7839	7849	7859
78	7869	7878	7880	7898	7907	7917	7927	7937	7946	7956
79	7966	7976	7985	7995	8005	8015	8024	8034	8044	8054
80	8064	8074	8083	8093	8103	8113	8122	8132	8142	8152
0.81	8162	8171	8181	8191	8200	8210	8220	8229	8239	8249
82	8259	8268	8278	8288	8297	8307	8317	8326	8336	8346
83	8356	8365	8375	8385	8394	8404	8414	8423	8433	8443
84	8453	8462	8472	8482	8491	8501	8511	8520	8530	8540
85	8550	8559	8569	8579	8588	8598	8608	8617	8627	8637
0.86	8647	8656	8666	8676	8685	8695	8705	8714	8724	8734
87	8744	8753	8763	8773	8782	8792	8802	8811	8821	8831
88	8841	8850	8860	8870	8879	8889	8899	8908	8918	8928
89	8938	8947	8957	8967	8976	8986	8996	9005	9015	9025
90	9035	9044	9054	9064	9073	9083	9093	9102	9112	9122
0.91	9132	9141	9151	9161	9170	9180	9190	9199	9209	6219
92	9229	9238	9248	9258	9267	9277	9287	9296	9306	9316
93	9326	9335	9345	9355	9364	9374	9384	9393	9403	9413
94	9423	9432	9442	9452	9461	9471	9481	9490	9500	9510
95	9520	9529	9539	9548	9558	9567	9577	9587	9596	9606
96	9616	9625	9635	9644	9654	9663	9673	9683	9692	9702
97	9712	9721	9731	9740	9750	9759	9769	9779	9788	9798
98	9809	9817	9827	9836	9846	9855	9865	9875	9884	9894
99	9904	9913	9923	9932	9942	9951	9961	9971	9980	0.9990
1.00	1.000	–	–	–	–	–	–	–	–	–

0.01	0.0103	114	124	134	145	155	165	176	186	196
2	206	217	227	237	248	258	268	279	289	299
3	309	320	330	340	350	360	371	381	391	401
4	411	422	432	442	453	463	473	484	494	504
5	514	524	534	545	555	565	575	586	596	606
0.06	616	626	636	647	657	667	677	688	698	708
7	718	728	738	749	759	769	779	790	800	810
8	820	830	840	851	861	871	881	892	902	912
9	922	933	943	953	964	974	984	995	1005	1015
0.10	0.1025	1035	1045	1056	1066	1076	1086	1097	1107	1117
0.11	1127	1137	1147	1158	1168	1178	1188	1199	1209	1219
12	1229	1239	1249	1260	1270	1280	1290	1301	1311	1321
13	1331	1342	1352	1362	1373	1383	1393	1404	1414	1424
14	1434	1445	1455	1465	1475	1485	1496	1506	1516	1526
15	1536	1547	1557	1567	1577	1587	1598	1608	1618	1628
0.16	1638	1649	1659	1669	1679	1689	1700	1710	1720	1730
17	1740	1751	1761	1771	1881	1791	1802	1812	1822	1832
18	1842	1853	1863	1873	1883	1893	1904	1914	1924	1934
19	1944	1954	1964	1974	1985	1995	2005	2015	2025	2035
20	2045	2056	2066	2076	2087	2097	2107	2117	2127	2137
0.21	2147	2158	2168	2178	2188	2198	2209	2219	2229	2239
22	2249	2260	2270	2280	2290	2300	2311	2321	2331	2341
23	2351	2361	2371	2381	2392	2402	2412	2422	2432	2442
24	2452	2463	2473	2483	2493	2503	2514	2524	2534	2544
25	2554	2565	2575	2585	2595	2605	2616	2626	2636	2646
0.26	2656	2666	2676	2686	2697	2707	2717	2727	2737	2747
27	2757	2767	2777	2787	2798	2808	2818	2828	2838	2848
28	2858	2868	2878	2888	2899	2909	2919	2929	2939	2949
29	2959	2969	2979	2989	3000	3010	3020	3030	3040	3050
30	3060	3070	3080	3090	3101	3111	3121	3131	3141	3151
0.31	3161	3171	3181	3191	3201	3212	3222	3232	3242	3252
32	3262	3273	3283	3293	3303	3313	3324	3334	3344	3354
33	3364	3374	3384	3394	3404	3415	3425	3435	3445	3455
34	3465	3475	3485	3495	3505	3516	3526	3536	3546	3556
35	3566	3576	3586	3596	3606	3617	3627	3637	3647	3657
0.36	3667	3677	3687	3697	3707	3718	3728	3738	3748	3758
37	3768	3778	3788	3798	3808	3818	3828	3838	3848	3858
38	3868	3878	3888	3898	3908	3919	3929	3939	3949	3959
39	3969	3979	3989	3999	4009	4020	4030	4040	4050	4060
40	4070	4080	4090	4100	4110	4120	4130	4140	4150	4160
0.41	4170	4180	4190	4200	4210	4220	4231	4241	4251	4261
42	4271	4281	4291	4301	4311	4321	4332	4342	4352	4362
43	4372	4382	4392	4402	4412	4422	4432	4442	4452	4462
44	4472	4482	4492	4502	4512	4523	4533	4543	4553	4563
45	4573	4583	4593	4603	4613	4623	4633	4643	4653	4663
0.46	4673	4683	4693	4703	4713	4723	4734	4744	4754	4764
47	4774	4784	4794	4804	4814	4824	4835	4845	4855	4865
48	4875	4885	4895	4905	4915	4925	4935	4945	4955	4965
49	4975	4985	4995	5005	5015	5025	5035	5045	5055	5065
50	0.5075	5085	5095	5105	5115	5125	5135	5145	5155	5165

52	5275	5285	5295	5305	5315	5325	5335	5345	5355	5365
53	5375	5385	5395	5405	5415	5425	5435	5445	5455	5465
54	5475	5485	5495	5505	5515	5525	5535	5545	5555	5565
55	5575	5584	5594	5604	5614	5624	5634	5644	5654	5664
0.56	5674	5683	5693	5703	5713	5723	5733	5743	5753	5763
57	5773	5782	5792	5802	5812	5822	5832	5842	5852	5862
58	5872	5882	5892	5902	5912	5922	5932	5942	5952	5962
59	5972	5981	5991	6001	6011	6021	6031	6041	6051	6061
60	6071	6080	6090	6100	6110	6120	6130	6140	6150	6160
0.61	6170	6180	6190	6200	6210	6220	6230	6240	6250	6260
62	6270	6279	6289	6299	6309	6319	6329	6339	6349	6359
63	6369	6378	6388	6398	6408	6418	6428	6438	6448	6458
64	6468	6477	6487	6497	6507	9517	6527	6537	6547	6557
65	6567	6576	6586	6596	6606	6616	6626	6637	6647	6657
0.66	6666	6675	6685	6695	6705	6715	6725	6735	6745	6755
67	6765	6774	6784	6794	6804	6814	6824	6834	6844	6854
68	6864	6873	6883	6893	6903	6913	6923	6933	6943	6953
69	6963	6972	6982	6992	7002	7012	7022	7032	7042	7052
70	7062	7071	7081	7091	7101	7111	7121	7131	7141	7151
0.71	7161	7170	7180	7190	7200	7210	7220	7230	7240	7250
72	7260	7269	7279	7289	7300	7309	7319	7329	7339	7349
73	7359	7368	7378	7388	7398	7408	7418	7428	7438	7448
74	7458	7467	7377	7487	7497	7507	7517	7527	7537	7547
75	7557	7566	7576	7586	7596	7606	7615	7625	7635	7645
0.76	7655	7665	7675	7685	7695	7705	7714	7724	7734	7744
77	7754	7764	7774	7784	7794	7804	7813	7823	7833	7843
78	7853	7863	7873	7883	7893	7903	7912	7922	7932	7942
79	7952	7962	7971	7981	7991	8001	8010	8020	8030	8040
80	8050	8060	8069	8079	8089	8099	8109	8118	8128	8138
.81	8148	8158	8167	8177	8187	8197	8207	8216	8226	8236
82	8246	8256	8265	8275	8285	8295	8305	8314	8324	8334
83	8344	8354	8363	8373	8383	8393	8403	8413	8422	8432
84	8442	8452	8461	8471	8481	8491	8501	8510	8520	8530
85	8540	8550	8559	8569	8579	8589	8599	8608	8618	8628
0.86	8638	8648	8657	8667	8677	8687	8697	8706	8716	8726
87	8736	8745	8755	8765	8774	8784	8794	8803	8813	8823
88	8833	8843	8853	8863	8872	8882	8892	8902	8912	8921
89	8931	8941	8951	8961	8970	8980	8990	9000	9010	9019
90	9029	9039	9049	9058	9068	9078	9087	9097	9107	9116
0.91	9126	9136	9146	9155	9165	9175	9184	9194	9204	9213
92	9223	9233	9243	9252	9262	9272	9281	9291	9301	9310
93	9320	9330	9340	9350	9360	9369	9379	9389	9398	9408
94	9418	9428	9437	9447	9457	9466	9476	9486	9495	9505
95	9515	9525	9534	9544	9554	9563	9573	9583	9592	9602
0.96	9612	9622	9631	9641	9651	9660	9670	9680	9689	9699
97	9709	9719	9728	9738	9748	9757	9767	9777	9786	9796
98	9806	9816	9825	9335	9845	9854	9864	9874	9883	9893
99	9903	9913	9922	9932	9942	9951	9971	9961	9980	9990
1.00	1.000	–	–	–	–	–	–	–	–	–

B \ Δ	0.07	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
0.70	595	844	900	965	1036	1100	1165	1228	1300	1370	1439
0.75	587	826	880	940	1006	1065	1125	1190	1255	1320	1389
0.80	579	809	860	915	977	1030	1090	1152	1210	1275	1339
0.85	572	792	840	890	949	1000	1060	1115	1170	1230	1289
0.90	565	775	820	870	922	975	1030	1079	1130	1185	1243
0.95	558	758	800	850	898	950	1000	1045	1095	1145	1199
1.00	551	741	780	830	874	925	970	1013	1060	1105	1157
1.05	544	724	760	810	850	900	940	982	1025	1070	1116
1.10	537	708	743	790	827	875	910	951	995	1035	1075
1.15	530	692	725	770	802	850	880	926	965	1005	1048
1.20	523	676	710	750	784	820	855	903	940	980	1018
1.25	516	661	695	730	764	800	835	880	915	955	990
1.30	509	646	680	710	746	780	820	859	890	930	967
1.35	502	634	665	700	730	765	805	840	870	910	946
1.40	495	623	650	685	715	750	790	822	845	890	925
1.45	488	612	640	675	702	745	775	805	830	870	906
1.50	481	601	630	660	690	730	760	788	818	850	887
1.55	475	592	620	650	679	715	745	775	803	830	870
1.60	469	584	610	640	669	700	730	762	788	815	853
1.65	464	577	600	630	659	690	715	749	773	800	838
1.70	459	570	590	620	649	680	705	735	760	785	823
1.75	454	563	585	610	641	670	695	725	750	775	809
1.80	449	556	580	605	633	660	685	715	740	765	795
1.85	445	549	575	600	625	650	675	704	730	750	781
1.90	442	543	570	595	617	640	665	694	720	745	768
1.95	439	537	565	590	610	630	650	684	710	735	757
2.00	435	532	560	585	603	620	645	674	700	725	747
2.05	433	527	555	580	596	610	635	664	690	715	737
2.10	430	522	550	574	590	600	625	654	680	705	727
2.15	427	517	545	568	584	595	615	645	670	695	718
2.20	424	512	540	562	578	590	610	636	660	685	709
2.25	421	507	535	556	572	585	605	628	650	675	700
2.30	419	503	530	550	566	580	600	620	640	665	691
2.35	417	499	525	545	560	575	595	615	635	655	683
2.40	415	495	520	540	554	570	590	610	630	650	675
2.45	413	492	515	535	548	565	585	605	625	645	667
2.50	411	489	510	530	542	560	580	600	620	640	659
2.55	409	486	505	525	538	555	575	595	615	635	652
2.60	407	483	500	520	533	550	570	590	610	630	646
2.65	405	480	495	515	528	545	565	585	605	624	640
2.70	403	477	490	510	523	540	560	580	600	618	634
2.75	402	474	485	505	520	535	555	575	595	612	628
2.80	401	471	482	500	517	530	550	570	590	606	622
2.85	399	468	479	497	514	527	547	566	585	600	616
2.90	398	465	476	494	511	524	544	562	580	595	611
2.95	397	462	473	492	508	522	541	558	575	590	606
3.00	396	459	470	490	506	520	538	555	570	580	601
$(1 - z_0)^2$	.3453	.5549	.5900	.6214	.6487	.6727	.6926	.7111	.7280	.7425	.7571

0.70	1439	1520	1595	1670	1745	1817	1900	1975	2060	2145	2230
0.75	1389	1460	1525	1595	1670	1741	1820	1895	1975	2055	2140
0.80	1339	1405	1470	1535	1600	1666	1740	1815	1890	1965	2050
0.85	1289	1350	1410	1475	1535	1598	1665	1735	1805	1880	1960
0.90	1243	1295	1350	1415	1470	1534	1595	1660	1720	1800	1880
0.95	1199	1250	1305	1365	1420	1480	1540	1600	1660	1725	1800
1.00	1157	1210	1265	1320	1370	1429	1490	1540	1600	1660	1725
1.05	1116	1170	1220	1275	1325	1383	1435	1485	1545	1605	1665
1.10	1075	1130	1180	1230	1280	1335	1390	1440	1495	1550	1610
1.15	1048	1100	1145	1195	1245	1300	1350	1395	1445	1500	1560
1.20	1018	1065	1110	1160	1210	1260	1305	1350	1400	1450	1515
1.25	990	1035	1080	1125	1175	1225	1270	1315	1365	1415	1475
1.30	967	1010	1055	1095	1140	1185	1230	1280	1330	1380	1435
1.35	946	990	1030	1070	1110	1157	1200	1245	1295	1345	1395
1.40	925	965	1005	1045	1085	1126	1170	1210	1260	1310	1355
1.45	906	950	985	1020	1060	1097	1140	1180	1230	1275	1315
1.50	887	930	965	1000	1035	1070	1110	1150	1200	1240	1285
1.55	870	910	945	980	1010	1046	1085	1125	1170	1210	1250
1.60	853	890	925	955	988	1023	1060	1100	1140	1180	1220
1.65	838	870	900	930	965	1000	1035	1075	1110	1150	1195
1.70	823	850	880	915	945	980	1015	1050	1085	1120	1170
1.75	809	830	865	900	935	965	995	1030	1060	1100	1150
1.80	795	820	850	880	915	943	975	1010	1040	1080	1125
1.85	781	805	835	865	900	930	960	990	1020	1060	1105
1.90	768	795	820	850	885	915	945	975	1005	1040	1080
1.95	757	782	810	835	870	900	930	960	990	1020	1060
2.00	747	772	797	825	857	887	915	945	975	1005	1040
2.05	737	762	787	815	845	875	900	930	960	990	1020
2.10	727	750	775	800	830	855	885	915	945	975	1000
2.15	718	740	765	790	815	840	870	900	925	955	980
2.20	709	730	750	775	80[illegible]	825	855	885	910	940	965
2.25	700	722	740	765	790	815	842	870	895	920	950
2.30	691	713	730	756	779	804	829	854	879	905	935
2.35	683	703	723	747	767	793	816	840	865	890	920
2.40	675	695	715	735	757	783	804	829	850	875	905
2.45	667	687	707	728	743	772	794	816	840	865	890
2.50	659	680	700	719	737	764	786	811	831	855	880
2.55	652	672	692	712	731	756	778	800	822	845	870
2.60	646	665	685	705	725	748	770	790	813	835	860
2.65	640	658	678	698	719	740	762	782	804	826	850
2.70	634	652	672	691	713	732	754	776	796	817	840
2.75	628	646	666	686	706	726	747	768	788	808	830
2.80	622	640	660	680	700	720	740	760	780	800	820
2.85	616	635	654	647	694	714	733	754	772	794	815
2.90	611	629	648	667	686	706	726	746	766	787	810
2.95	606	624	642	660	678	698	718	739	760	781	805
3.00	601	620	638	656	674	694	714	734	755	776	800
$(1 - z_0)^2$	.7571	.7688	.7799	.7903	.8003	.8100	.8184	.8260	.8330	.8391	.8446

0.70	2230	2320	2415	[illegible]	[illegible]	[illegible]	2800	[illegible]	3005	3110	3215
0.75	2140	2225	231[illegible]	24[illegible]	[illegible]	[illegible]	[illegible]	276[illegible]	[illegible]	296[illegible]	30[illegible]
0.80	2050	2130	2210	2290	2375	2460	[illegible]	263[illegible]	2725	2820	294[illegible]
0.85	19[illegible]	2040	2120	[illegible]	2275	2355	2435	[illegible]	2600	2685	2775
0.90	1880	1955	2030	2100	2170	2240	2310	2390	2470	2550	2640
0.95	1800	1870	1940	20[illegible]	[illegible]70	2135	2205	2270	2350	2430	2515
1.00	1725	1790	18[illegible]	1910	1970	2040	2110	2180	2250	2320	2400
1.05	1665	1720	1770	1830	1890	1960	2030	2100	2165	2230	2300
1.10	1610	1665	1705	1760	1825	1890	1955	2020	2080	2150	2215
1.15	1560	1610	1616	1710	1770	1830	1890	1950	2010	2080	2145
1.20	1515	1565	1615	1665	1720	1770	1830	1885	1940	2010	2060
1.25	1475	1520	1570	1620	1670	1720	1770	1825	1875	1930	2000
1.30	1435	1475	1525	1570	1615	1670	1725	1765	1815	1870	1930
1.35	1395	1435	1480	1525	1570	1620	1665	1715	1760	1810	1865
1.40	1355	1400	1445	1490	1530	1580	1620	1670	1715	1760	1810
1.45	1315	1365	1405	1450	1485	1540	1580	1625	1670	1710	1750
1.50	1285	1330	1370	1410	1450	1495	1540	1580	1620	1660	1700
1.55	1250	1295	1335	1375	1415	1460	1500	1540	1580	1620	1660
1.60	1220	1260	1300	1340	1380	1420	1460	1500	1540	1580	1620
1.65	1195	1225	1255	1305	1340	1380	1420	1460	1500	1545	1580
1.70	1170	1195	1230	1270	1305	1345	1385	1425	1465	1510	1545
1.75	1150	1165	1200	1240	1270	1310	1350	1390	1420	1480	1510
1.80	1125	1145	1170	1205	1235	1275	1315	1355	1385	1445	1475
1.85	1105	1125	1145	1180	1205	1240	1280	1320	1350	1410	1445
1.90	1080	1100	1120	1150	1185	1215	1250	1290	1320	1375	1415
1.95	1060	1080	1100	1130	1165	1190	1230	1265	1300	1340	1390
2.00	1040	1060	1080	1110	1145	1175	1210	1250	1280	1320	1360
2.05	1020	1040	1060	1090	1125	1155	1190	1230	1260	1290	1330
2.10	1000	1020	1040	1070	1105	1135	1170	1210	1240	1270	1310
2.15	980	1000	1020	1050	1085	1115	1150	1190	1220	1250	1285
2.20	965	985	1005	1035	1065	1100	1130	1165	1200	1230	1265
2.25	950	970	990	1020	1050	1080	1110	1140	1175	1210	1240
2.30	935	955	975	1000	1030	1060	1090	1120	1155	1190	1220
2.35	920	940	960	980	1010	1040	1070	1100	1135	1170	1200
2.40	905	925	945	965	995	1030	1050	1080	1115	1150	1180
2.45	890	910	930	950	980	1005	1030	1060	1095	1130	1160
2.50	880	900	920	940	965	990	1015	1045	1080	1110	1140
2.55	870	890	910	930	955	980	1005	1030	1065	1095	1125
2.60	860	880	900	920	945	970	995	1020	1050	1080	1110
2.65	850	870	890	910	935	960	985	1010	1035	1065	1095
2.70	840	860	880	900	925	950	975	1000	1025	1050	1080
2.75	830	850	870	890	915	940	965	990	1015	1040	1070
2.80	820	840	860	880	905	930	950	980	1005	1030	1060
2.85	815	830	850	870	895	920	945	970	995	1020	1050
2.90	810	825	845	865	885	910	935	960	985	1010	1040
2.95	805	820	840	860	880	905	930	955	980	1005	1030
3.00	800	815	835	855	875	900	925	950	975	1000	1020
$(1 - z_0)^2$	.8446	.8501	.8556	.8611	.8663	.8720	.8766	.8807	.8847	.8885	.8920

0.70	3210	3325	3445	3560	367[illegible]	380[illegible]	394[illegible]	1080	4225	4365	[illegible]
0.75	3060	3160	3270	3380	3495	3610	3730	3850	[illegible]980	4110	42[illegible]
0.80	2915	3005	3110	3215	3320	3425	3535	3650	3770	3890	4020
0.85	2775	2860	2960	3050	3150	3250	3350	3460	3570	3690	3815
0.90	2640	2725	2810	2900	2990	3080	3180	3280	3390	3510	3615
0.95	2515	2595	2680	2765	2850	2940	3035	3130	3230	3335	3440
1.00	2400	2485	2570	2645	2730	2820	2900	2995	3085	3180	3285
1.05	2300	2380	2465	2536	2615	2700	2775	2860	2950	3030	3140
1.10	2215	2285	2360	2430	2500	2515	2615	2715	2815	2900	3000
1.15	2145	2205	2275	2335	2400	2470	2545	2625	2710	2785	2880
1.20	2060	2130	2190	2250	2315	2380	2455	2530	2610	2680	2760
1.25	2000	2055	2115	2175	2235	2300	2370	2440	2515	2585	2660
1.30	1930	1985	2045	2100	2160	2220	2285	2350	2420	2490	2560
1.35	1865	1920	1975	2030	2090	2150	2215	2275	2340	2400	2470
1.40	1810	1860	1910	1965	2020	2080	2145	2100	2260	2320	2380
1.45	1750	1800	1850	1905	1965	2020	2075	2130	2190	2245	2300
1.50	1700	1750	1800	1850	1900	1950	2010	2065	2120	2175	2235
1.55	1660	1707	1750	1800	1850	1900	1950	2005	2060	2115	2175
1.60	1620	1660	1705	1755	1800	1850	1900	1950	2000	2055	2115
1.65	1580	1625	1670	1715	1760	1805	1850	1900	1950	2000	2065
1.70	1545	1585	1630	1670	1715	1760	1805	1855	1900	1955	2015
1.75	1510	1550	1590	1630	1675	1720	1760	1805	1855	1905	1965
1.80	1475	1515	1550	1590	1635	1680	1720	1765	1810	1860	1910
1.85	1445	1480	1515	1555	1600	1640	1680	1725	1770	1810	1870
1.90	1415	1450	1485	1525	1570	1615	1655	1695	1735	1780	1830
1.95	1390	1420	1460	1500	1540	1580	1620	1665	1705	1745	1790
2.00	1360	1395	1435	1475	1515	1550	1590	1635	1670	1710	1750
2.05	1330	1370	1405	1450	1490	1520	1560	1605	1635	1675	1710
2.10	1310	1345	1380	1425	1465	1495	1530	1570	1605	1640	1675
2.15	1285	1320	1355	1400	1440	1470	1500	1540	1575	1610	1640
2.20	1265	1225	1330	1375	1410	1445	1475	1520	1550	1580	1610
2.25	1240	1270	1305	1350	1385	1420	1450	1495	1525	1555	1585
2.30	1220	1250	1280	1325	1360	1395	1430	1470	1500	1530	1560
2.35	1200	1230	1260	1300	1335	1375	1405	1445	1475	1505	1535
2.40	1180	1210	1240	1280	1315	1345	1380	1420	1450	1480	1510
2.45	1160	1190	1220	1260	1295	1320	1355	1395	1425	1455	1485
2.50	1140	1170	1200	1240	1275	1300	1330	1370	1400	1430	1460
2.55	1125	1150	1185	1220	1255	1280	1310	1345	1375	1405	1435
2.60	1110	1135	1170	1200	1235	1260	1290	1320	1350	1380	1410
2.65	1095	1120	1155	1185	1215	1240	1270	1300	1325	1355	1385
2.70	1080	1105	1140	1170	1200	1225	1250	1280	1305	1330	1360
2.75	1070	1095	1125	1155	1285	1210	1235	1260	1285	1310	1340
2.80	1060	1085	1110	1140	1170	1195	1220	1245	1270	1295	1325
2.85	1050	1075	1095	1125	1155	1180	1205	1230	1255	1280	1310
2.90	1040	1065	1085	1110	1140	1165	1190	1215	1240	1265	1300
2.95	1030	1055	1075	1100	1125	1150	1175	1200	1225	1255	1290
3.00	1020	1045	1065	1090	1110	1035	1160	1185	1215	1245	1280
$(1 - z_0)^2$	.8920	.8952	.8985	.9016	.9047	.9076	.9105	.9131	.9157	.9179	.9201

0.70	4520	4665	4815	4970	5125	5280					
0.75	4240	4385	4530	4680	4830	4980	5140				
0.80	4020	4155	4290	4430	4570	4710	4860	5010			
0.85	3815	3945	4075	4205	4335	4470	4615	4760	4910	5065	
0.90	3615	3740	3865	3985	4105	4235	4375	4515	4660	4805	4950
0.95	3440	3550	3665	3775	3885	4000	4135	4270	4410	4545	4680
1.00	3285	3390	3495	3595	3695	3800	3925	4055	4130	4320	4450
1.05	3140	3240	3340	3435	3525	3620	3735	3855	3980	4100	4220
1.10	3000	3090	3185	3275	3360	3450	3555	3665	3780	3890	4000
1.15	2880	2970	3055	3140	3220	3310	3400	3500	3610	3715	3820
1.20	2760	2850	2940	3030	3120	3210	3300	3390	3480	3570	3660
1.25	2660	2745	2830	2915	3000	3085	3170	3260	3345	3430	3520
1.30	2560	2645	2730	2815	2900	2985	3070	3150	3230	3310	3390
1.35	2470	2550	2630	2710	2790	2870	2950	3030	3110	3190	3270
1.40	2380	2460	2535	2615	2690	2775	2845	2925	3000	3080	3160
1.45	2300	2375	2455	2530	2610	2685	2760	2835	2910	2985	3060
1.50	2235	2310	2380	2455	2525	2595	2665	2740	2810	2885	2960
1.55	2175	2240	2310	2380	2450	2520	2590	2660	2730	2800	2870
1.60	2115	2180	2250	2315	2380	2445	2515	2580	2650	2710	2780
1.65	2065	2125	2185	2250	2315	2380	2445	2510	2575	2640	2700
1.70	2015	2070	2135	2195	2255	2315	2375	2435	2495	2555	2620
1.75	1965	2020	2080	2140	2195	2255	2315	2370	2430	2490	2550
1.80	1910	1965	2025	2080	2135	2190	2250	2300	2365	2420	2480
1.85	1870	1925	1980	2035	2090	2145	2200	2255	2310	2360	2420
1.90	1830	1885	1940	1990	2045	2100	2150	2205	2260	2310	2365
1.95	1790	1845	1900	1950	2000	2055	2105	2155	2210	2255	2310
2.00	1750	1805	1860	1910	1960	2010	2060	2110	2160	2205	2255
2.05	1710	1765	1820	1870	1920	1970	2015	2065	2115	2155	2205
2.10	1675	1730	1785	1835	1885	1930	1975	2025	2070	2110	2155
2.15	1640	1700	1755	1805	1850	1895	1935	1985	2030	2065	2105
2.20	1610	1675	1725	1770	1815	1860	1900	1945	1990	2025	2060
2.25	1585	1650	1700	1740	1785	1830	1865	1910	1955	1985	2020
2.30	1560	1625	1675	1710	1755	1800	1830	1875	1920	1950	1980
2.35	1535	1600	1650	1680	1725	1770	1800	1840	1885	1915	1945
2.40	1510	1575	1625	1655	1695	1740	1770	1810	1850	1880	1910
2.45	1485	1550	1600	1630	1665	1710	1740	1780	1820	1845	1875
2.50	1460	1525	1575	1605	1640	1680	1710	1750	1790	1815	1840
2.55	1435	1505	1550	1580	1615	1645	1680	1720	1760	1785	1810
2.60	1410	1475	1525	1555	1590	1620	1655	1690	1730	1755	1780
2.65	1385	1430	1485	1515	1565	1595	1630	1665	1700	1725	1750
2.70	1360	1420	1450	1480	1520	1550	1585	1615	1650	1680	1720
2.75	1340	1395	1425	1455	1495	1525	1555	1585	1625	1650	1695
2.80	1325	1370	1400	1430	1470	1500	1535	1560	1600	1625	1670
2.85	1310	1350	1380	1410	1445	1475	1505	1535	1575	1600	1645
2.90	1300	1330	1360	1390	1425	1455	1480	1515	1550	1575	1620
2.95	1290	1320	1350	1380	1410	1440	1470	1500	1530	1560	1600
3.00	1280	1310	1340	1370	1400	1430	1460	1490	1520	1550	1580
$(1 - z_0)^2$	.9201	.9222	.9243	.9264	.9285	.9305	.9324	.9342	.9359	.9376	.9392

0.70											
0.75											
0.80											
0.85											
0.90	4950	5095									
0.95	4680	4825	4970	5120							
1.00	4450	4590	4735	4885	5040						
1.05	4220	4355	4495	4640	4790	4945	5105				
1.10	4000	4130	4265	4405	4550	4700	4855	5015			
1.15	3820	3940	4065	4195	4330	4470	4615	4765	4920	5080	
1.20	3660	3770	3885	4005	4130	4260	4395	4540	4690	4845	5000
1.25	3520	3620	3725	3835	3940	4070	4195	4330	4470	4615	4760
1.30	3390	3480	3575	3675	3780	3890	4005	4130	4260	4400	4530
1.35	3270	3375	3480	3585	3690	3795	3900	4005	4110	4220	4330
1.40	3160	3255	3350	3450	3550	3650	3750	3850	3950	4050	4150
1.45	3060	3150	3240	3330	3420	3510	3600	3695	3790	3885	3980
1.50	2960	3045	3130	3215	3300	3385	3470	3560	3650	3740	3830
1.55	2870	2950	3030	3116	3200	3285	3370	3455	3540	3625	3710
1.60	2780	2860	2940	3020	3100	3180	3260	3345	3430	3515	3600
1.65	2700	2775	2850	2930	3010	3090	3170	3250	3330	3410	3495
1.70	2620	2695	2770	2845	2920	2995	3070	3150	3230	3310	3390
1.75	2550	2620	2690	2765	2840	2915	2990	3065	3140	3215	3290
1.80	2480	2550	2620	2690	2760	2830	2900	2975	3050	3125	3200
1.85	2420	2485	2550	2620	2690	2760	2830	2900	2970	3040	3110
1.90	2365	2430	2495	2560	2625	2690	2755	2820	2890	2960	3030
1.95	2310	2370	2430	2495	2560	2625	2690	2755	2820	2885	2950
2.00	2255	2315	2375	2435	2495	2555	2620	2685	2750	2815	2880
2.05	2205	2265	2325	2385	2445	2505	2565	2625	2685	2745	2810
2.10	2155	2210	2265	2325	2385	2445	2505	2565	2625	2685	2745
2.15	2105	2160	2215	2270	2325	2380	2440	2500	2560	2620	2680
2.20	2060	2115	2170	2225	2280	2335	2390	2445	2500	2560	2620
2.25	2020	2070	2120	2175	2230	2285	2340	2395	2450	2505	2560
2.30	1980	2030	2080	2130	2180	2230	2285	2340	2395	2450	2505
2.35	1945	1995	2045	2095	2145	2195	2245	2295	2345	2395	2450
2.40	1910	1955	2000	2050	2100	2150	2200	2250	2300	2350	2400
2.45	1875	1920	1965	2010	2055	2100	2150	2200	2250	2300	2350
2.50	1840	1885	1935	1975	2020	2065	2110	2155	2205	2255	2305
2.55	1810	1855	1900	1945	1990	2035	2080	2125	2170	2215	2260
2.60	1780	1820	1860	1905	1950	1995	2040	2085	2130	2175	2220
2.65	1750	1790	1830	1870	1910	1955	2000	2045	2090	2135	2180
2.70	1720	1760	1800	1840	1880	1920	1965	2010	2055	2100	2145
2.75	1695	1735	1775	1815	1855	1895	1935	1975	2020	2065	2110
2.80	1670	1710	1750	1790	1830	1870	1910	1950	1990	2035	2080
2.85	1645	1685	1725	1765	1805	1845	1885	1925	1965	2005	2050
2.90	1620	1660	1700	1740	1780	1820	1860	1900	1940	1980	2025
2.95	1600	1640	1680	1720	1760	1800	1840	1880	1920	1960	2000
3.00	1580	1620	1660	1700	1740	1780	1820	1860	1900	1940	1980
$(1 - z_0)^2$	.9392	.9408	.9423	.9438	.9452	.9466	.9480	.9492	.9506	.9517	.9530

0.70											
0.75											
0.80											
0.85											
0.90											
0.95											
1.00											
1.05											
1.10											
1.15											
1.20	5000										
1.25	4750	4910	5060								
1.30	4530	4670	4810	4950	5090						
1.35	4330	4455	4580	4710	4840	4970	5110				
1.40	4150	4260	4370	4485	4600	4720	4850	4990	5140		
1.45	3980	4080	4190	4305	4420	4540	4670	4810	4960	5120	
1.50	3830	3925	4025	4135	4255	4385	4525	4680	4845	5020	5200
1.55	3710	3800	3895	4000	4115	4240	4375	4520	4675	4840	5010
1.60	3600	3685	3775	3875	3985	4105	4230	4365	4510	4665	4825
1.65	3495	3580	3665	3760	3865	3980	4100	4230	4365	4510	4660
1.70	3390	3475	3555	3645	3745	3855	3970	4090	4220	4360	4505
1.75	3290	3365	3440	3525	3620	3725	3835	3950	4080	4220	4365
1.80	3200	3275	3345	3425	3515	3615	3720	3830	3955	4090	4235
1.85	3110	3180	3255	3335	3425	3525	3630	3735	3850	3975	4110
1.90	3030	3100	3175	3255	3345	3445	3545	3645	3755	3870	3995
1.95	2950	3015	3085	3160	3245	3340	3435	3535	3645	3760	3885
2.00	2880	2945	3015	3090	3175	3270	3365	3460	3560	3665	3780
2.05	2810	2875	2940	3010	3090	3180	3270	3365	3465	3565	3685
2.10	2745	2805	2865	2930	3010	3100	3190	3285	3385	3485	3595
2.15	2680	2740	2800	2865	2940	3025	3110	3200	3300	3400	3510
2.20	2620	2680	2735	2795	2865	2945	3025	3115	3215	3315	3425
2.25	2560	2615	2670	2730	2800	2880	2960	3045	3140	3235	3345
2.30	2505	2560	2610	2665	2730	2805	2885	2970	3065	3160	3265
2.35	2450	2505	2555	2610	2675	2750	2825	2905	2995	3085	3190
2.40	2400	2450	2495	2545	2605	2675	2750	2830	2920	3010	3115
2.45	2350	2400	2440	2490	2545	2610	2685	2785	2855	2945	3045
2.50	2305	2355	2395	2445	2495	2555	2625	2700	2790	2880	2980
2.55	2260	2305	2345	2395	2445	2505	2575	2650	2740	2825	2920
2.60	2220	2265	2305	2355	2405	2465	2535	2605	2690	2770	2860
2.65	2180	2225	2265	2310	2355	2410	2475	2545	2630	2710	2800
2.70	2145	2190	2230	2275	2320	2375	2440	2505	2585	2660	2745
2.75	2110	2155	2195	2240	2285	2340	2405	2465	2535	2610	2690
2.80	2080	2125	2165	2205	2245	2295	2355	2415	2485	2560	2640
2.85	2050	2095	2135	2175	2215	2260	2315	2370	2435	2510	2590
2.90	2025	2070	2110	2150	2190	2230	2280	2330	2390	2465	2545
2.95	2000	2040	2085	2125	2165	2205	2250	2300	2360	2430	2505
3.00	1980	2020	2065	2105	2145	2185	2230	2275	2335	2400	2470
$(1 - z_0)^2$	.9530	.9541	.9552	.9563	.9573	.9585	.9595	.9606	.9615	.9624	.9633

0.70	0.16	0.30	0.33	0.35	0.37	0.39	0.41	0.43	0.44	0.45	0.46
0.75	17	33	36	38	41	43	45	47	49	51	52
0.80	18	36	39	42	44	47	49	51	54	56	58
0.85	20	39	42	45	47	50	52	55	57	59	61
0.90	21	42	45	48	50	53	56	57	59	61	63
0.95	23	45	48	50	53	56	58	60	63	65	67
1.00	24	47	50	53	57	60	63	65	68	70	72
1.05	26	48	53	57	61	64	67	69	72	75	77
1.10	27	51	56	60	65	68	72	74	77	80	82
1.15	28	54	59	64	69	73	76	79	82	85	87
1.20	30	57	63	68	73	77	81	84	88	91	93
1.25	31	60	66	72	77	82	86	90	93	96	98
1.30	32	63	69	75	81	86	91	96	99	1.02	1.04
1.35	33	67	74	80	86	91	96	1.01	1.04	07	10
1.40	35	70	77	84	91	97	1.02	07	11	14	17
1.45	36	74	81	88	95	1.01	07	13	17	20	23
1.50	38	77	85	93	1.00	07	13	19	23	27	31
1.55	39	81	89	97	05	12	19	25	30	34	38
1.60	40	84	93	1.02	11	17	24	31	36	41	46
1.65	42	88	98	07	16	23	30	37	43	49	54
1.70	44	92	1.02	12	22	30	37	44	51	57	63
1.75	45	96	07	17	27	36	44	52	59	66	72
1.80	47	1.00	11	22	33	42	51	59	67	74	81
1.85	49	04	16	28	39	49	58	67	75	83	91
1.90	51	09	22	34	46	57	66	75	84	93	2.01
1.95	52	13	26	39	52	63	74	84	93	2.02	11
2.00	54	17	32	46	59	71	82	92	2.03	12	21
2.05	56	22	37	51	65	78	90	2.02	12	22	31
2.10	58	27	43	58	73	86	99	12	22	32	42
2.15	60	32	48	64	80	94	2.08	22	33	44	54
2.20	62	37	54	71	87	2.02	17	32	44	56	67
2.25	63	42	60	73	95	11	28	43	56	68	80
2.30	65	48	66	84	2.02	20	37	54	68	81	94
2.35	67	53	73	92	11	30	48	66	80	94	3.08
2.40	69	59	80	2.00	20	39	58	77	93	3.08	23
2.45	71	65	87	08	29	49	69	88	3.05	22	38
2.50	73	71	94	16	39	60	80	3.00	18	36	53
2.55	75	76	2.01	26	49	70	91	12	31	50	68
2.60	77	83	09	35	60	82	3.04	26	46	66	85
2.65	79	89	17	44	71	95	18	41	62	83	4.03
2.70	81	96	25	54	82	3.07	32	57	79	4.00	21
2.75	83	2.03	33	63	93	20	46	72	95	18	41
2.80	85	09	41	73	3.04	32	60	88	4.13	38	63
2.85	88	17	50	83	15	45	75	4.04	31	58	85
2.90	90	24	58	92	26	58	90	21	50	79	5.08
2.95	92	32	68	3.03	38	72	4.05	38	70	5.01	32
3.00	94	39	76	13	50	86	21	56	90	24	57

0.70	0.46	0.46	0.46	0.47	0.48	0.49	0.49	0.49	0.49	0.51	0.51
0.75	52	53	53	54	55	55	56	56	56	57	57
0.80	58	58	59	60	60	61	61	62	62	63	63
0.85	61	62	63	64	64	65	65	66	67	67	67
0.90	63	64	66	66	68	68	69	69	70	70	71
0.95	67	68	70	71	72	73	74	74	75	75	76
1.00	72	74	75	77	77	79	79	80	81	81	82
1.05	77	78	80	82	83	84	85	85	87	87	88
1.10	82	84	86	87	89	90	92	92	93	94	95
1.15	87	89	91	93	94	96	97	98	99	1.00	1.01
1.20	93	95	97	99	1.01	1.02	1.04	1.05	1.06	07	08
1.25	98	1.01	1.03	1.05	07	09	11	12	14	15	16
1.30	1.04	07	10	12	14	16	18	20	21	22	23
1.35	10	13	16	19	21	24	26	27	29	30	31
1.40	17	21	24	27	29	31	33	34	37	38	40
1.45	23	27	31	34	37	39	42	44	45	47	49
1.50	31	34	39	42	49	47	50	52	53	55	58
1.55	38	43	47	50	54	57	59	61	63	65	67
1.60	46	51	55	59	63	66	69	71	73	75	77
1.65	54	59	64	68	72	76	78	81	83	86	88
1.70	63	68	73	78	82	86	89	92	95	97	99
1.75	72	78	83	88	92	96	2.00	2.03	2.06	2.09	2.11
1.80	81	87	93	98	2.02	2.07	11	14	17	20	23
1.85	91	98	2.04	2.09	14	18	22	26	30	33	36
1.90	2.01	2.08	15	20	26	30	34	39	42	46	50
1.95	11	18	29	31	37	42	47	52	56	60	64
2.00	21	29	36	43	49	55	60	65	70	75	79
2.05	31	39	47	55	62	68	73	79	84	89	94
2.10	42	51	60	67	75	81	88	93	99	3.04	3.10
2.15	54	64	73	81	90	97	3.03	3.10	3.16	22	27
2.20	67	78	88	97	3.05	3.13	20	27	34	40	46
2.25	80	92	3.02	3.12	22	30	38	45	52	58	65
2.30	94	3.06	18	29	39	48	56	63	71	78	83
2.35	3.08	21	34	45	55	65	75	84	92	99	4.06
2.40	23	36	49	61	73	84	95	4.04	4.14	4.22	30
2.45	38	52	66	80	92	4.04	4.16	27	37	41	54
2.50	53	68	83	97	4.11	24	37	49	60	70	80
2.55	68	84	4.00	4.16	30	44	59	72	85	96	5.06
2.60	85	4.01	18	34	51	66	83	98	5.12	5.23	34
2.65	4.03	22	40	57	73	89	5.06	5.22	37	49	61
2.70	21	42	61	80	97	5.13	30	46	62	75	89
2.75	41	63	84	5.03	5.21	38	57	74	91	6.07	6.21
2.80	63	86	5.08	28	47	66	85	6.05	6.23	40	56
2.85	85	5.10	34	55	75	95	6.15	36	56	75	92
2.90	5.08	36	62	86	6.07	6.27	48	69	90	7.09	7.26
2.95	32	63	90	6.14	37	59	79	7.01	7.23	44	65
3.00	57	91	6.21	48	71	93	7.14	36	58	80	8.01

0.70	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.51	0.51
0.75	57	57	58	58	58	58	57	57	57	57	57
0.80	63	64	63	63	63	63	63	63	63	63	63
0.85	67	68	68	69	69	69	68	69	69	69	69
0.90	71	72	72	72	73	73	73	73	73	73	73
0.[illegible]	76	76	77	77	77	77	77	78	78	78	78
1.[illegible]	82	82	82	83	83	84	84	85	85	85	85
1.05	88	88	89	89	89	90	90	91	92	92	92
1.10	95	95	96	96	97	98	98	98	99	99	1.00
1.15	1.01	1.02	1.03	1.03	1.04	1.04	1.05	1.06	1.06	1.07	07
1.20	09	09	10	11	11	12	12	13	13	14	14
1.25	16	17	18	18	19	20	20	21	21	22	22
1.30	23	25	26	26	27	27	28	29	29	29	29
1.35	31	33	34	35	35	37	37	37	40	38	38
1.40	40	41	43	43	45	46	46	47	47	47	47
1.45	49	50	52	53	54	55	56	56	57	57	57
1.50	58	60	61	63	64	65	66	67	67	70	67
1.55	67	69	71	73	75	76	77	78	78	78	78
1.60	77	80	82	83	85	86	89	88	89	89	89
1.65	88	90	92	94	96	97	99	2.00	2.01	2.01	2.02
1.70	99	2.02	2.04	2.05	2.07	2.08	2.10	11	12	13	14
1.75	2.11	13	16	18	20	21	23	24	26	27	27
1.80	23	26	28	31	33	35	36	38	40	41	42
1.85	36	39	42	45	47	49	51	53	54	56	57
1.90	50	53	56	59	62	64	66	68	70	71	72
1.95	64	68	71	75	78	80	83	85	87	88	89
2.	79	83	87	91	95	97	3.00	3.02	3.04	3.05	3.07
2.[illegible]	94	99	3.03	3.08	3.11	3.15	17	19	21	22	24
2.10	3.10	3.14	20	24	29	32	35	37	39	40	42
2.15	27	32	38	43	48	53	55	58	60	62	64
2.20	46	52	58	63	68	72	76	79	81	84	86
2.25	65	71	77	82	87	92	96	99	4.03	4.06	4.09
2.30	83	90	96	4.02	4.07	4.12	4.16	4.21	25	28	32
2.35	4.06	4.13	4.19	25	31	36	42	46	51	55	59
2.40	30	36	43	49	56	61	67	73	78	83	87
2.45	54	63	70	5.77	83	89	95	5.01	5.06	5.11	5.15
2.50	80	88	96	03	5.10	5.17	5.23	29	34	39	43
2.55	5.06	5.15	5.24	32	40	47	54	60	66	72	76
2.60	34	43	52	61	69	77	85	92	99	6.05	6.10
2.65	61	70	79	89	98	6.06	6.15	6.24	6.31	38	44
2.70	89	98	6.09	6.19	6.28	37	46	55	63	70	77
2.75	6.21	6.33	45	56	67	77	87	97	7.05	7.13	7.20
2.80	56	70	84	97	7.09	7.19	7.29	7.38	47	55	62
2.[illegible]	92	7.07	7.21	7.34	47	59	69	79	88	97	8.05
2.90	7.26	40	55	69	82	95	8.08	8.19	8.30	8.40	49
2.95	65	83	99	8.15	8.30	8.44	57	69	80	91	9.00
3.00	8.01	8.19	8.38	56	74	90	9.06	9.20	9.33	9.45	55

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.70	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.49	0.49	0.49	0.49
0.75	57	57	57	56	56	56	56	55	55	55	55
0.80	63	63	62	62	62	62	62	61	61	61	60
0.85	69	69	68	68	68	68	67	67	67	66	66
0.90	73	73	72	72	72	71	71	71	70	70	70
.95	78	78	78	78	78	77	77	77	76	76	76
1.00	85	85	85	84	84	84	83	83	83	83	82
1.05	92	92	92	91	91	90	90	90	89	89	88
1.10	1.00	99	99	99	98	97	97	96	96	96	95
1.15	07	1.07	1.	1.06	1.05	1.05	1.04	1.03	1.03	1.03	1.02
1.20	14	14	14	14	14	13	13	12	12	11	10
1.25	22	22	21	21	21	20	20	20	19	19	18
1.30	29	29	29	29	29	28	28	28	27	27	26
1.35	38	38	38	38	38	37	37	37	37	36	35
1.40	47	47	47	47	47	46	46	46	45	45	45
1.45	57	57	57	57	57	56	56	56	55	55	54
1.50	67	68	68	68	67	67	66	66	65	65	65
1.55	78	78	78	78	78	78	77	77	76	76	76
1.60	89	90	90	90	90	90	89	89	89	88	88
1.65	2.02	2.02	2.02	2.03	2.03	2.02	2.02	2.02	2.01	2.01	2.00
1.70	14	14	14	15	15	15	15	15	14	14	13
1.75	27	28	29	29	29	29	29	29	29	29	28
1.80	42	42	43	44	44	44	44	44	43	43	42
1.85	57	57	58	58	59	59	59	59	59	58	58
1.90	72	73	73	73	74	74	74	74	74	74	74
1.95	89	90	91	91	92	92	92	92	92	91	91
.00	3.07	3.07	3.08	3.09	3.09	3.09	3.10	3.10	3.09	3.09	3.08
2.05	24	25	26	27	28	28	28	28	28	27	27
2.10	42	44	45	46	47	48	49	49	48	48	47
2.15	64	66	68	69	70	70	71	71	71	70	69
2.20	86	88	90	92	93	94	95	95	95	94	93
2.25	4.09	4.11	4.14	4.15	4.17	4.18	4.18	4.19	4.19	4.18	4.17
2.30	32	36	39	41	42	43	44	44	44	43	43
2.35	59	63	67	69	70	71	72	72	73	72	71
2.40	87	90	93	96	99	5.00	5.00	5.01	5.00	5.00	5.00
2.45	5.15	5.19	5.23	5.26	5.28	29	30	30	30	30	30
2.50	43	46	49	52	54	55	57	58	59	60	60
2.55	76	80	83	87	89	91	92	93	94	95	95
2.60	6.10	6.15	6.20	6.23	6.25	6.27	6.29	6.31	6.32	6.33	6.33
2.65	44	49	53	57	60	63	65	67	69	70	71
2.70	77	83	88	92	96	99	7.02	7.04	7.06	7.09	7.10
2.75	7.20	7.26	7.31	7.36	7.41	7.45	48	50	52	4	54
2.80	62	69	76	82	87	91	95	98	99	8.00	8.01
.85	8.05	8.13	8.20	8.26	8.32	8.37	8.41	8.44	8.46	48	50
2.90	49	57	64	70	76	81	86	90	94	97	9.00
2.95	9.00	9.08	9.14	9.20	9.26	9.31	9.36	9.40	9.44	9.47	50
3.00	55	63	70	78	85	92	98	10.04	10.09	10.15	10.19

0.70	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.46	0.46	0.46	0.45
0.75	55	54	54	54	53	53	53	52	52	51	51
0.80	60	60	60	59	59	58	58	58	58	57	57
0.85	66	66	65	65	65	64	64	63	63	62	62
0.90	70	69	69	68	68	67	67	66	66	66	65
0.95	76	74	74	73	72	72	71	71	70	70	70
1.00	82	81	80	80	79	78	77	77	77	76	75
1.05	88	87	87	86	85	85	84	84	83	82	82
1.10	95	94	94	93	92	92	91	90	90	89	89
1.15	1.02	1.01	1.01	1.00	99	98	98	97	97	96	96
1.20	10	10	09	08	1.07	1.06	1.06	0.05	1.04	1.03	1.03
1.25	18	17	16	15	14	13	13	12	12	11	10
1.30	26	25	24	23	22	20	20	20	20	19	18
1.35	35	34	33	32	31	30	29	29	28	28	27
1.40	45	43	43	42	41	40	39	39	38	37	36
1.45	54	54	53	52	51	50	49	48	47	46	45
1.50	65	64	63	62	61	61	60	59	58	57	56
1.55	76	75	74	74	73	72	71	70	69	68	66
1.60	88	87	86	86	84	84	82	81	80	79	77
1.65	2.00	2.00	99	98	97	96	94	93	92	91	89
1.70	13	12	2.12	2.11	2.10	2.09	2.08	2.07	2.05	2.04	2.03
1.75	28	27	26	25	23	22	21	20	18	17	16
1.80	42	42	41	39	38	37	35	34	33	31	30
1.85	58	57	56	55	54	53	51	50	48	46	45
1.90	74	73	72	72	70	69	68	66	64	63	60
1.95	91	90	89	88	87	86	84	82	81	79	77
2.00	3.08	3.08	3.07	3.07	3.06	3.04	3.03	3.10	3.00	98	96
2.05	27	26	26	25	24	23	22	21	19	3.17	3.15
2.10	47	47	47	46	45	43	42	41	39	37	35
2.15	69	68	67	66	65	64	63	62	60	59	57
2.20	93	92	91	90	88	87	86	85	84	82	80
2.25	4.17	4.16	4.15	4.13	4.12	4.11	4.10	4.09	4.08	4.06	4.04
2.30	43	42	41	40	39	37	36	35	33	31	29
2.35	71	71	70	68	67	65	63	61	59	57	55
2.40	5.00	99	99	98	97	95	93	91	88	86	84
2.45	30	5.30	5.29	5.29	5.28	5.27	5.25	5.23	5.20	5.18	5.15
2.50	60	61	61	61	61	60	59	57	55	53	50
2.55	95	96	96	96	96	96	95	93	91	89	87
2.60	6.33	6.34	6.34	6.34	6.33	6.32	6.31	6.29	6.28	6.26	6.23
2.65	71	72	73	73	72	72	71	69	67	65	62
2.70	7.10	7.11	7.12	7.12	7.12	7.11	7.10	7.09	7.07	7.05	7.03
2.75	54	55	55	55	55	54	54	52	51	49	48
2.80	8.01	8.02	8.02	8.03	8.03	8.02	8.02	8.01	8.00	98	97
2.85	50	51	53	54	54	54	54	53	53	8.51	8.49
2.90	9.00	9.04	9.06	9.08	9.08	9.09	9.09	9.08	9.07	9.06	9.05
2.95	50	53	56	58	59	61	62	62	62	62	61
3.00	10.19	10.21	10.24	10.25	10.26	10.26	10.27	10.26	10.26	10.25	10.24

B	0.60	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70
0.70	0.45	0.45	0.44	0.44	0.44	0.44	0.43	0.42	0.42	0.41	0.41
0.75	51	50	50	49	49	48	48	47	47	46	45
0.80	57	56	56	55	54	54	53	53	52	51	50
0.85	62	61	61	60	60	59	58	58	57	56	55
0.90	65	64	64	63	62	62	61	61	60	59	59
0.95	70	69	69	68	67	67	66	65	64	63	63
1.00	76	75	74	74	73	72	71	70	69	68	68
1.05	82	81	80	79	78	78	77	76	75	74	74
1.10	89	88	87	86	85	84	83	82	81	80	80
1.15	95	94	93	92	91	90	89	88	87	86	86
1.20	1.03	1.02	1.00	99	98	97	97	96	95	94	93
1.25	10	10	09	1.08	1.07	1.05	1.04	1.03	1.02	1.01	99
1.30	18	18	17	16	15	13	12	11	09	08	1.07
1.35	27	26	25	24	22	21	20	19	17	16	15
1.40	36	35	34	33	31	30	29	28	26	25	23
1.45	45	45	43	42	41	40	38	36	35	33	32
1.50	56	55	53	52	51	49	48	46	45	43	42
1.55	66	65	64	62	61	60	58	57	55	53	51
1.60	77	76	75	74	72	71	69	67	66	64	62
1.65	89	88	87	86	84	83	81	79	77	75	73
1.70	2.03	2.02	2.00	99	97	95	94	92	89	87	85
1.75	16	15	14	2.13	2.11	2.09	2.07	2.05	2.03	2.01	98
1.80	30	28	27	26	24	23	21	19	17	14	2.12
1.85	45	44	43	41	40	38	36	34	31	29	26
1.90	60	59	58	56	54	53	51	48	46	44	42
1.95	77	77	75	74	72	70	68	66	63	61	58
2.00	96	95	93	92	90	88	86	84	81	78	75
2.05	3.15	3.14	3.12	3.11	3.09	3.06	3.04	3.02	99	96	94
2.10	35	34	32	30	28	25	23	21	3.18	3.15	3.12
2.15	57	55	53	51	49	46	44	41	39	36	32
2.20	80	78	76	74	71	69	66	63	60	57	54
2.25	4.04	4.02	4.00	97	95	92	89	86	83	80	77
2.30	29	27	25	4.23	4.20	4.17	4.13	4.10	4.06	4.03	4.00
2.35	55	52	49	47	44	41	39	36	33	30	27
2.40	84	81	78	75	72	69	67	64	61	58	55
2.45	5.15	5.12	5.09	5.07	5.04	5.01	98	95	92	89	86
2.50	50	47	44	41	38	35	5.32	5.28	5.25	5.22	5.18
2.55	87	83	80	77	74	71	67	64	60	57	53
2.60	6.23	6.21	6.18	6.15	6.12	6.08	6.05	6.02	98	94	90
2.65	62	60	57	54	50	47	44	40	6.36	6.32	6.28
2.70	7.03	7.01	99	97	94	91	87	83	79	74	68
2.75	48	46	7.44	7.41	7.39	7.36	7.32	7.27	7.23	7.18	7.12
2.80	97	95	93	91	88	85	81	76	72	66	61
2.85	8.49	8.46	8.44	8.42	8.38	8.35	8.31	8.27	8.22	8.17	8.11
2.90	9.05	9.02	9.00	97	93	89	86	81	76	71	66
2.95	61	61	59	9.56	9.53	9.49	9.44	9.39	9.34	9.28	9.23
3.00	10.24	10.23	10.21	10.18	10.15	10.12	10.08	10.04	9.99	94	89

B											
0.70	0.41	0.40	0.40	0.39	0.38	0.38	0.37	0.37	0.36	0.35	0.35
0.75	45	45	44	44	43	42	42	41	41	40	39
0.80	50	50	49	48	48	47	46	45	44	44	43
0.85	52	55	54	53	52	51	50	49	48	48	47
0.90	59	58	57	57	56	55	54	53	52	51	50
0.95	63	62	62	61	60	59	58	57	56	55	54
1.00	68	67	66	65	65	64	63	62	61	60	59
1.05	74	73	72	71	70	69	68	67	66	65	64
1.10	80	78	77	76	75	74	73	72	71	70	69
1.15	86	84	83	82	81	80	79	78	77	76	75
1.20	93	92	91	90	88	87	86	84	83	81	80
1.25	99	98	97	96	94	93	92	91	89	88	87
1.30	1.07	1.06	1.04	1.03	1.02	1.00	99	97	96	95	94
1.35	15	14	12	11	09	08	1.06	1.05	1.03	1.02	1.00
1.40	23	22	20	19	17	16	14	13	11	09	08
1.45	32	30	29	28	26	24	23	22	20	18	16
1.50	42	40	39	37	35	33	31	30	28	26	24
1.55	51	50	48	47	45	43	41	39	37	35	33
1.60	62	61	59	58	56	54	52	49	47	45	43
1.65	73	72	70	68	66	64	62	60	57	55	53
1.70	85	83	82	80	78	75	73	71	68	66	63
1.75	98	97	95	93	91	88	86	83	81	78	75
1.80	2.12	2.10	2.08	2.06	2.03	2.01	98	96	93	90	88
1.85	26	24	22	20	17	14	2.12	2.09	2.06	2.04	2.01
1.90	42	40	37	34	32	29	26	24	21	18	15
1.95	58	55	51	48	46	43	40	37	35	32	30
2.00	75	72	68	65	61	58	55	53	50	47	45
2.05	94	90	86	83	79	76	73	70	67	64	61
2.10	3.12	3.09	3.06	3.02	99	95	92	88	85	82	78
2.15	32	29	26	23	3.19	3.16	3.12	3.09	3.05	3.01	97
2.20	54	51	47	44	41	38	34	30	26	22	3.19
2.25	77	74	71	67	64	60	57	53	49	46	42
2.30	4.00	97	93	90	87	83	80	77	73	70	66
2.35	27	4.24	4.20	4.17	4.14	4.10	4.07	4.03	99	96	93
2.40	55	52	49	45	42	39	34	30	4.26	4.22	4.18
2.45	86	83	79	76	72	67	63	59	54	49	43
2.50	5.18	5.15	5.11	5.07	5.02	97	92	87	82	76	70
2.55	53	48	45	40	35	5.30	5.25	5.19	5.12	5.05	98
2.60	90	86	82	78	73	69	63	57	50	43	5.35
2.65	6.28	6.24	6.20	6.15	6.10	6.05	99	92	84	76	67
2.70	68	64	59	59	49	44	6.38	6.31	6.23	6.15	6.06
2.75	7.12	7.07	7.02	98	93	88	81	73	65	56	46
2.80	61	56	51	7.45	7.40	7.34	7.27	7.20	7.11	7.02	93
2.85	8.11	8.06	8.01	95	89	83	77	70	62	54	7.45
2.90	66	60	54	8.48	8.42	8.35	8.28	8.21	8.14	8.06	8.00
2.95	9.23	9.16	9.10	9.04	98	91	86	79	73	67	62
3.00	89	84	78	72	9.65	9.58	51	9.44	9.37	9.30	9.22

B											
0.70	0.151	0.298	0.321	0.343	0.363	0.381	0.401	0.422	0.437	0.441	0.446
0.75	158	329	354	378	401	424	447	469	485	501	516
0.80	175	360	386	411	436	461	485	509	530	551	571
0.85	191	390	417	443	468	493	517	541	564	586	606
0.90	208	418	446	472	497	521	544	567	586	604	621
0.95	223	443	474	500	523	544	563	581	598	614	628
1.00	238	462	493	517	537	555	572	588	603	618	632
1.05	252	473	505	527	545	561	571	592	606	620	633
1.10	264	478	514	539	548	564	579	593	607	620	633
1.15	280	478	514	539	548	564	579	593	607	620	632
1.20	293	476	512	537	546	562	577	591	604	617	629
1.25	305	474	503	525	543	559	574	588	601	613	625
1.30	317	470	497	519	538	554	569	583	596	608	619
1.35	324	463	487	509	529	547	563	577	590	602	612
1.40	328	456	479	500	520	538	554	569	582	593	603
1.45	329	449	470	491	511	529	545	559	572	583	594
1.50	329	441	462	482	501	518	534	548	561	574	586
1.55	327	433	454	474	492	508	524	539	553	566	578
1.60	322	424	445	465	483	500	516	531	545	558	570
1.65	315	416	437	457	475	492	508	523	537	550	562
1.70	308	408	430	450	468	485	501	516	530	543	555
1.75	302	400	424	444	462	478	493	508	522	535	548
1.80	296	393	415	435	453	470	486	501	515	528	541
1.85	290	386	408	428	446	463	479	494	508	521	534
1.90	284	380	402	422	440	457	473	488	502	515	528
1.95	278	375	397	417	434	450	466	481	495	509	522
2.00	273	370	392	411	428	444	460	475	489	503	516
2.05	268	365	386	405	422	438	454	469	484	498	511
2.10	263	360	380	399	416	432	448	463	478	492	505
2.15	258	355	374	392	410	427	443	458	473	487	500
2.20	254	350	369	387	405	422	438	453	468	482	496
2.25	249	346	365	383	400	417	433	448	463	477	490
2.30	245	341	360	378	395	412	428	443	458	472	486
2.35	241	336	355	373	390	407	423	438	453	467	481
2.40	238	332	350	368	385	402	418	434	449	463	477
2.45	234	328	346	364	381	398	414	430	445	459	473
2.50	231	324	342	360	377	394	410	426	441	455	469
2.55	228	321	339	357	374	391	407	422	437	451	465
2.60	224	318	335	352	369	385	401	417	432	447	461
2.65	221	314	331	348	365	382	398	414	429	443	457
2.70	219	311	328	345	362	378	394	410	425	439	453
2.75	216	308	325	342	358	374	390	406	421	435	449
2.80	213	304	321	338	355	371	387	403	418	432	445
2.85	210	301	318	335	352	368	384	399	414	428	441
2.90	208	298	315	332	349	365	380	395	410	424	437
2.95	205	294	311	328	345	361	376	391	406	420	433
3.00	0.203	0.291	0.308	0.325	0.342	0.358	0.373	0.388	0.402	0.416	0.429

B											
0.70	0.446	0.452	0.457	0.464	0.471	0.480	0.481	0.490	0.490	0.503	0.505
0.75	516	523	530	537	543	548	553	557	561	565	568
0.80	571	579	586	592	598	603	608	613	617	621	625
0.85	606	615	623	631	638	644	650	656	661	665	670
0.90	621	630	640	650	659	668	675	684	692	699	705
0.95	628	637	647	657	667	676	683	692	699	706	712
1.00	632	641	651	661	671	680	687	696	703	710	716
1.05	633	642	652	662	672	681	688	697	704	711	717
1.10	633	642	652	662	672	681	688	697	703	710	716
1.15	632	641	651	660	670	679	686	692	700	707	713
1.20	629	638	648	657	667	676	683	689	696	702	708
1.25	626	634	643	652	662	671	678	684	690	696	702
1.30	619	628	637	646	656	665	672	678	684	690	696
1.35	612	621	630	638	647	656	663	669	675	681	687
1.40	603	612	621	629	638	647	654	660	666	672	678
1.45	594	603	612	620	629	638	645	651	657	663	669
1.50	586	595	604	612	621	630	637	643	649	655	661
1.55	578	587	596	604	612	621	628	633	638	649	650
1.60	570	579	588	596	604	613	620	625	630	636	642
1.65	562	571	580	588	596	605	612	617	622	628	634
1.70	555	564	573	581	589	599	605	609	615	621	627
1.75	548	557	566	574	582	592	598	602	608	614	620
1.80	541	550	559	567	575	585	591	595	601	607	613
1.85	534	543	552	560	568	578	584	588	594	600	606
1.90	528	537	546	554	562	572	578	582	588	594	600
1.95	522	531	540	548	556	577	572	576	582	588	594
2.00	516	525	534	542	550	560	566	570	576	582	588
2.05	511	520	529	537	545	555	561	565	571	577	583
2.10	505	515	524	532	540	550	556	560	566	572	578
2.15	500	510	519	527	535	545	551	555	561	567	573
2.20	496	505	514	522	530	540	546	550	556	562	568
2.25	490	500	509	517	525	535	541	545	551	557	564
2.30	486	495	504	512	521	531	537	541	547	553	560
2.35	481	490	499	507	517	527	533	537	543	549	556
2.40	477	486	495	503	513	523	529	533	539	545	552
2.45	473	482	491	494	509	519	525	529	535	541	548
2.50	469	478	487	493	505	515	521	525	531	538	545
2.55	465	474	483	491	501	511	517	521	527	534	542
2.60	461	470	479	487	497	507	513	517	523	531	539
2.65	457	466	475	483	493	503	509	513	520	528	536
2.70	453	462	471	479	489	499	505	511	517	525	533
2.75	449	458	467	475	485	495	501	507	513	521	530
2.80	445	454	463	471	481	491	497	503	510	518	527
2.85	441	450	459	467	477	487	493	500	507	515	524
2.90	437	446	455	463	473	484	490	497	504	512	521
2.95	433	442	451	459	470	481	487	494	501	509	518
3.00	0.429	0.438	0.447	0.456	0.467	0.478	0.484	0.491	0.498	0.506	0.515

B											
0.70	0.497	0.502	0.505	0.510	0.513	0.514	0.514	0.513	0.511	0.509	0.507
0.75	568	570	571	571	571	571	570	568	566	564	565
0.80	625	638	629	630	629	629	628	626	625	623	623
0.85	670	675	679	683	686	690	690	688	687	685	683
0.90	705	711	715	720	723	727	730	726	726	724	723
0.95	712	718	723	728	732	736	739	739	738	737	735
1.00	716	721	725	731	735	739	742	742	742	741	740
1.05	717	722	726	731	735	739	742	744	745	744	743
1.10	716	721	725	730	734	738	741	743	744	745	745
1.15	713	718	722	727	731	735	738	740	741	743	744
1.20	708	713	718	723	727	731	734	736	737	738	739
1.25	702	707	712	717	721	725	728	730	731	732	733
1.30	696	701	706	711	715	719	722	724	725	726	727
1.35	687	692	697	702	706	710	713	715	716	717	718
1.40	678	683	688	693	697	701	704	706	707	708	709
1.45	669	674	679	684	688	692	695	697	698	699	700
1.50	661	666	671	676	680	684	687	689	691	692	693
1.55	650	655	661	666	670	675	678	680	682	683	685
1.60	642	647	653	658	662	667	670	672	674	675	677
1.65	634	639	645	650	654	659	662	664	666	667	670
1.70	627	632	638	643	647	652	655	657	659	660	663
1.75	620	625	631	636	640	645	648	650	652	653	656
1.80	613	619	625	630	634	639	642	644	646	648	650
1.85	606	613	619	624	628	633	636	638	640	642	644
1.90	600	607	613	618	622	627	630	632	634	636	638
1.95	594	601	607	612	616	621	624	626	628	630	633
2.00	588	595	601	606	610	615	618	620	622	624	627
2.05	583	590	596	601	605	610	613	615	617	619	622
2.10	578	585	591	596	600	605	608	610	612	614	617
2.15	573	580	586	591	595	600	603	605	607	609	613
2.20	568	575	581	586	590	595	598	600	602	604	609
2.25	564	571	577	582	586	591	594	596	598	600	605
2.30	560	567	573	578	582	587	590	592	594	596	601
2.35	556	563	569	574	578	583	586	588	590	592	597
2.40	552	559	565	570	574	579	582	584	586	588	593
2.45	548	555	561	566	570	575	578	580	582	584	589
2.50	545	552	558	563	567	572	575	577	579	581	586
2.55	542	549	555	560	564	569	572	574	576	578	583
2.60	539	546	552	557	561	566	569	571	573	575	580
2.65	536	543	549	554	558	563	566	568	570	572	577
2.70	533	540	546	551	555	560	563	565	567	570	574
2.75	530	537	543	548	552	557	560	562	565	568	571
2.80	527	534	540	545	549	554	557	560	563	566	569
2.85	524	531	537	542	546	551	555	558	561	564	567
2.90	521	528	534	539	543	549	553	556	559	562	565
2.95	518	525	531	536	541	547	551	554	557	560	563
3.00	0.515	0.527	0.528	0.534	0.539	0.545	0.549	0.552	0.555	0.558	0.561

B											
0.70	0.507	0.505	0.503	0.500	0.500	0.495	0.492	0.490	0.490	0.485	0.482
0.75	565	563	562	560	558	555	553	550	548	545	542
0.80	623	621	620	618	615	613	611	608	605	602	599
0.85	683	681	679	677	675	672	669	666	663	660	656
0.90	723	721	719	716	713	710	707	703	700	697	692
.95	735	732	730	727	724	722	718	715	712	709	705
1.00	740	738	736	734	731	729	725	722	718	715	711
1.05	743	741	739	737	735	732	729	727	724	721	718
1.10	745	744	740	739	737	734	731	729	726	723	720
1.15	744	743	740	738	736	733	730	728	725	723	720
1.20	739	738	736	735	733	731	728	726	723	721	719
1.25	733	732	731	730	729	727	724	722	720	718	716
1.30	727	726	725	724	723	720	719	718	716	714	712
1.35	718	717	716	715	714	713	711	710	709	707	705
1.40	709	708	707	706	705	704	703	702	701	700	699
1.45	700	699	698	697	696	696	695	694	693	692	692
1.50	693	692	691	690	689	689	689	689	688	687	686
1.55	685	684	683	683	682	682	682	682	681	681	680
1.60	677	677	676	676	676	676	676	676	675	675	675
1.65	670	670	669	669	669	669	669	669	669	669	669
1.70	663	663	663	664	664	664	664	664	664	664	664
1.75	656	656	656	657	657	658	658	658	659	659	659
1.80	650	651	651	562	652	563	653	653	654	654	654
1.85	644	645	645	646	646	647	647	648	649	649	650
1.90	638	639	639	640	641	642	642	643	644	645	646
.95	633	634	634	635	636	637	638	639	640	641	642
2.00	627	628	629	630	631	632	633	634	635	636	637
2.05	622	623	624	625	626	627	628	629	630	631	632
2.10	617	618	619	620	621	622	623	624	625	626	627
2.15	613	614	616	617	618	619	620	621	622	623	624
2.20	609	610	612	613	614	615	616	617	618	619	620
2.25	605	606	608	609	610	611	612	613	614	615	616
2.30	601	602	604	606	607	608	609	610	611	612	613
2.35	597	598	600	602	603	604	605	606	607	608	609
2.40	593	594	596	598	600	601	602	603	604	605	606
2.45	589	591	593	595	597	598	599	600	601	602	603
2.50	586	588	590	592	594	595	596	597	598	599	600
2.55	583	585	587	589	591	592	593	594	595	596	597
2.60	580	582	584	586	588	589	590	591	592	593	594
2.65	577	579	581	583	585	586	587	589	590	591	592
2.70	574	576	578	580	582	584	585	587	588	589	590
2.75	517	573	575	577	579	581	583	585	586	587	588
2.80	569	571	573	575	577	579	581	583	584	585	586
2.85	567	569	571	573	575	577	579	581	582	583	584
2.90	565	567	569	571	573	575	577	579	580	581	582
2.95	563	565	567	569	571	573	575	577	578	579	580
3.00	0.561	0.563	0.565	0.567	0.569	0.571	0.573	0.575	0.576	0.577	0.578

B											
0.70	0.482	0.480	0.477	0.474	0.471	0.470	0.464	0.460	0.45[illegible]	0.45[illegible]	[illegible]
0.75	542	538	535	532	528	524	521	516	512	50[illegible]	[illegible]
0.80	599	596	593	590	586	583	579	575	571	568	564
0.85	656	653	649	645	641	637	633	628	623	619	614
0.90	692	688	683	679	674	670	665	659	654	648	643
0.95	705	701	697	693	688	683	678	673	668	663	658
1.00	711	707	702	690	694	690	685	680	676	671	666
1.05	718	714	710	706	702	697	692	688	683	678	674
1.10	720	716	713	709	705	701	697	693	688	684	680
1.15	720	716	714	710	707	703	699	696	691	688	684
1.20	719	715	714	710	706	704	701	698	694	691	687
1.25	716	713	711	708	705	703	700	698	695	692	689
1.30	712	709	708	706	703	700	697	695	693	690	687
1.35	705	703	702	700	698	695	692	690	688	685	682
1.40	699	698	697	695	693	690	687	685	683	680	677
1.45	692	691	690	698	688	686	682	680	678	675	672
1.50	688	685	684	683	682	681	679	676	673	670	667
1.55	680	680	679	678	677	676	674	671	668	665	662
1.60	675	675	674	673	672	671	669	666	663	660	658
1.65	669	668	668	667	667	666	665	662	659	656	654
1.70	664	663	663	662	662	661	660	658	655	653	650
1.75	659	658	658	658	658	657	657	655	652	650	647
1.80	654	654	654	654	654	653	651	649	647	645	643
1.85	650	650	650	650	650	649	648	646	644	642	640
1.90	646	646	646	646	64[illegible]	644	643	642	640	638	636
1.95	642	642	642	642	641	640	639	638	637	635	633
2.00	637	637	637	637	636	635	634	633	632	631	630
2.05	632	632	632	632	631	631	631	630	629	628	627
2.10	627	628	629	628	628	628	627	626	625	624	623
2.15	624	625	625	625	624	624	624	623	622	621	620
2.20	620	621	622	622	621	620	620	619	619	618	618
2.25	616	617	618	618	617	617	617	616	615	614	613
2.30	613	614	615	615	614	613	613	612	612	611	610
2.35	609	610	611	612	611	610	610	609	609	608	607
2.40	606	607	608	608	607	606	606	605	605	604	604
2.45	603	604	605	605	604	603	603	602	602	601	601
2.50	600	601	602	602	601	600	600	599	598	598	598
2.55	597	598	599	599	598	597	597	596	596	595	595
2.60	594	595	596	598	595	594	594	593	593	592	592
2.65	592	593	594	594	593	592	592	591	591	590	590
2.70	598	591	592	592	591	590	590	589	589	588	588
2.75	588	589	590	590	589	588	588	587	587	586	586
2.80	585	587	588	588	587	586	586	585	585	584	584
2.85	584	585	586	585	585	584	584	583	583	582	582
2.90	582	583	584	584	583	582	582	581	581	580	580
2.95	580	581	582	582	581	580	580	579	579	578	578
3.00	0.579	0.579	0.580	0.580	0.579	0.578	0.578	0.577	0.577	0.576	0.576

B											
0.70	0.449	0.445	0.440	0.436	0.431	0.426	0.421	0.416	0.411	0.406	0.401
0.75	503	498	494	489	484	479	473	468	462	456	450
0.80	563	558	552	546	540	534	528	521	515	507	500
0.85	614	609	603	697	591	585	578	571	564	556	549
0.90	643	637	631	626	620	614	609	602	596	589	581
0.95	658	653	648	642	637	631	626	619	613	607	600
1.00	666	661	657	652	647	642	637	631	625	619	613
1.05	674	669	665	660	656	652	647	642	637	631	626
1.10	680	676	672	668	663	659	654	650	645	640	634
1.15	684	680	676	672	667	663	658	654	650	645	639
1.20	687	683	679	675	670	666	661	657	653	642	643
1.25	689	685	681	676	671	667	662	658	654	649	644
1.30	687	683	679	674	669	665	660	656	652	648	643
1.35	683	678	674	670	665	661	656	652	648	644	639
1.40	677	673	669	665	660	656	652	648	644	640	635
1.45	672	668	664	660	656	652	648	644	640	636	631
1.50	667	664	660	656	652	648	644	640	636	632	628
1.55	662	659	656	652	648	644	640	636	632	628	624
1.60	658	655	562	648	645	641	637	633	629	625	621
1.65	654	651	648	644	641	637	633	629	625	629	617
1.70	650	647	644	641	638	634	630	626	622	618	614
1.75	647	644	641	638	635	631	627	623	619	615	611
1.80	643	640	637	634	631	628	624	620	616	612	608
1.85	640	637	634	631	628	625	621	617	613	609	605
1.90	636	634	631	628	625	622	618	614	610	605	602
1.95	633	631	629	626	623	620	616	612	608	604	600
2.00	630	628	626	624	621	618	614	610	606	602	598
2.05	627	625	623	621	618	615	611	607	603	599	595
2.10	623	621	619	617	615	612	608	604	600	596	593
2.15	620	618	616	614	612	609	606	602	598	594	591
2.20	617	616	614	612	610	607	604	600	596	592	589
2.25	613	612	611	609	607	604	601	597	593	590	587
2.30	610	609	608	607	605	602	599	595	592	588	585
2.35	607	606	605	604	603	600	597	593	590	587	584
2.40	604	603	602	601	600	598	595	591	588	585	582
2.45	601	600	599	598	597	596	593	589	586	583	580
2.50	598	597	596	595	594	593	590	587	584	581	578
2.55	595	594	593	592	591	590	588	585	582	579	576
2.60	592	591	590	589	588	587	585	582	579	576	573
2.65	590	589	588	587	586	585	583	580	577	574	571
2.70	588	587	586	585	584	583	581	578	575	572	569
2.75	586	585	584	583	582	581	579	576	573	570	567
2.80	584	583	582	581	580	579	577	575	572	569	566
2.85	582	581	580	579	578	577	575	573	570	567	564
2.90	580	579	578	577	576	575	573	571	568	565	562
2.95	578	577	576	575	574	573	571	569	567	564	561
3.00	0.576	0.575	0.574	0.573	0.572	0.571	0.569	0.567	0.565	0.562	0.559

B	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80
0.70	0.401	0.396	0.391	0.386	0.380	0.374	0.368	0.362	0.356	0.349	0.342
0.75	450	444	438	432	420	426	414	408	401	393	383
0.80	500	493	485	478	462	462	454	446	438	430	423
0.85	549	541	533	524	516	506	497	488	479	471	462
0.90	581	574	567	559	551	543	534	525	516	507	499
0.95	600	593	586	579	572	564	557	548	540	531	522
1.00	613	606	600	593	586	578	571	563	555	547	540
1.05	626	620	614	607	600	594	587	579	572	564	556
1.10	634	628	622	616	610	603	596	590	582	575	567
1.15	639	635	631	627	623	617	609	602	593	585	576
1.20	643	639	635	631	627	622	614	607	599	591	582
1.25	644	640	636	632	628	623	616	609	602	595	587
1.30	643	639	635	631	627	622	616	610	604	598	591
1.35	639	635	631	627	623	619	613	608	603	598	592
1.40	635	631	627	623	619	615	609	604	600	596	591
1.45	631	627	623	619	615	611	606	601	597	593	589
1.50	628	624	619	615	611	607	602	598	594	590	586
1.55	624	620	615	611	607	603	598	594	591	587	584
1.60	621	617	612	608	604	600	596	592	589	585	582
1.65	617	613	609	605	601	597	593	589	586	583	580
1.70	614	610	606	602	598	594	590	587	584	581	578
1.75	611	607	603	599	595	592	588	585	582	579	576
1.80	608	604	600	596	593	590	586	583	580	577	574
1.85	605	601	597	594	591	588	584	581	578	575	572
1.90	602	598	595	592	589	586	582	579	576	573	570
1.95	600	596	593	590	587	584	580	577	574	571	568
2.00	598	594	591	588	585	582	578	575	572	569	565
2.05	595	592	589	586	583	580	577	574	571	568	565
2.10	593	590	587	584	581	578	575	572	569	566	563
2.15	591	588	585	582	579	576	573	570	567	564	561
2.20	589	586	583	580	577	574	571	568	565	562	559
2.25	587	584	581	578	575	573	570	567	564	561	558
2.30	585	582	579	576	573	571	568	565	562	559	556
2.35	584	581	578	575	572	570	567	564	561	558	555
2.40	582	579	576	573	570	568	565	562	559	556	553
2.45	580	577	574	571	568	566	563	560	557	554	551
2.50	578	575	572	569	566	564	561	558	555	552	548
2.55	576	573	570	568	565	563	560	557	554	551	548
2.60	573	571	568	566	563	561	558	555	552	549	546
2.65	571	569	567	565	562	560	557	554	551	548	545
2.70	569	567	565	563	561	559	556	553	550	547	544
2.75	567	565	563	561	559	557	554	551	548	545	542
2.80	566	564	562	560	558	556	553	550	547	544	541
2.85	564	562	560	558	556	554	551	548	545	542	539
2.90	562	560	558	556	554	552	549	546	543	540	537
2.95	561	559	557	555	553	551	548	545	542	539	536
3.00	0.559	0.557	0.555	0.553	0.551	0.549	0.546	0.543	0.540	0.537	0.534

0.70	$\bar{1}$.9894	$\bar{1}$.9872	$\bar{1}$.9854	$\bar{1}$.9840	$\bar{1}$.9827	$\bar{1}$.9816	$\bar{1}$.9807	$\bar{1}$.9798
0.75	9886	9863	9844	9828	9815	9802	9792	9783
0.80	9879	9854	9834	9817	9802	9780	9778	9768
0.85	9871	9845	9823	9805	9789	9776	9763	9754
0.90	9863	9836	9812	9793	9777	9762	9749	9739
0.95	9855	9827	9802	9782	9765	9748	9735	9723
1.00	9847	9817	9791	9769	9751	9734	9720	9708
1.05	9840	9808	9780	9757	9738	9721	9706	9693
1.10	9832	9798	9769	9745	9725	9707	9691	9683
1.15	9824	9788	9750	9733	9712	9689	9677	9662
1.20	9817	9779	9738	9721	9699	9679	9682	9647
1.25	9809	9770	9737	9709	9686	9665	9647	9632
1.30	9800	9760	9726	9698	9673	9652	9633	9617
1.35	9793	9751	9716	9686	9660	9638	9618	9602
1.40	9785	9742	9704	9674	9647	9624	9604	9526
1.45	9777	9731	9693	9661	9633	9609	9589	9570
1.50	9769	9722	9682	9648	9620	9595	9574	9555
1.55	9761	9713	8672	9637	9608	9581	9559	9539
1.60	9754	9703	9661	9625	9594	9567	9543	9528
1.65	9745	9693	9649	9612	9581	9553	9529	9507
1.70	9737	9684	9638	9600	9566	9539	9513	9487
1.75	9730	9674	9628	9588	9554	9524	9499	9481
1.80	9721	9664	9616	9575	9541	9510	9483	9461
1.85	9713	9655	9605	9563	9527	9496	9468	9444
1.90	9705	9645	9593	9550	9513	9480	9453	9427
1.95	9697	9635	9583	9539	9500	9467	9438	9412
2.00	9689	9626	9571	9526	9486	9452	9422	9396
2.05	9680	9615	9560	9513	9472	9437	9406	9380
2.10	9673	9606	9548	9501	9459	9422	9390	9364
2.15	9665	9598	9540	9490	9448	9410	9379	9347
2.20	9652	9586	9523	9475	9431	9393	9365	9336
2.25	9648	9577	9514	9463	9417	9378	9344	9314
2.30	9641	9566	9503	9450	9404	9364	9329	9298
2.35	9632	9556	9490	9437	9390	9349	9312	9281
2.40	9625	9546	9480	9429	9376	9334	9297	9266
2.45	9616	9537	9469	9411	9362	9319	9278	9248
2.50	9608	9524	9453	9398	9348	9304	9260	9236
2.55	9600	9516	9446	9386	9334	9289	9249	9215
2.60	9591	9507	9434	9373	5321	9274	9233	9199
2.65	9582	9495	9420	9357	9320	9255	9214	9180
2.70	9575	9486	9410	9349	9285	9243	9200	9163
2.75	9569	9476	9399	9334	9276	9228	9184	9145
2.80	9558	9466	9387	6321	9262	9212	9168	9128
2.85	9552	9458	9376	9316	9265	9200	9155	9112
2.90	9542	9446	9366	9294	9234	9181	9135	9094
2.95	9534	9433	9359	9282	9221	9171	9118	9076
3.00	9525	9425	9341	9262	9205	9150	9104	9060

B	0.15	0.16	0.17	0.18	0.19	0.20	0.25	0.30	0.35
0.70	Ī.9790	Ī.9784	Ī.9778	Ī.9773	Ī.9768	Ī.9763	Ī.9748	Ī.9735	Ī.9727
0.75	9775	9768	9762	9756	9751	9746	9730	9716	9706
0.80	9760	9752	9745	9739	9733	9729	9714	9695	9686
0.85	9745	9736	9729	9722	9717	9711	9692	9765	9665
0.90	9729	9720	9712	9705	9699	9693	9674	9656	9645
0.95	9713	9711	9696	9689	9682	9675	9654	9635	9624
1.00	9697	9691	9679	9672	9664	9658	9635	9616	9604
1.05	9682	9672	9663	9654	9647	9640	9616	9596	9583
1.10	9662	9655	9646	9634	9629	9621	9597	9576	9562
1.15	9650	9638	9628	9621	9611	9600	9578	9555	9541
1.20	9639	9618	9611	9608	9594	9587	9562	9535	9519
1.25	9618	9607	9590	9585	9576	9568	9539	9514	9490
1.30	9611	9590	9578	9568	9559	9550	9519	9494	9477
1.35	9587	9573	9561	9550	9521	9532	9501	9473	9456
1.40	9575	9557	9543	9533	9511	9513	9480	9453	9434
1.45	9554	9540	9531	9515	9505	9495	9461	9431	9412
1.50	9549	9518	9510	9498	9486	9476	9441	9410	9391
1.55	9526	9507	9492	9472	9469	9458	9421	9390	9369
1.60	9507	9489	9479	9462	9450	9439	9401	9360	9348
1.65	9501	9472	9458	9447	9431	9421	9381	9356	9334
1.70	9474	9455	9440	9426	9413	9402	9361	9327	9303
1.75	9459	9438	9422	9407	9395	9383	9341	9304	9281
1.80	9439	9421	9404	9389	9375	9364	9321	9282	9258
1.85	9422	9402	9402	9387	9371	9345	9300	9261	9235
1.90	9406	9388	9369	9353	9341	9326	9279	9240	9213
1.95	9390	9370	9351	9335	9320	9306	9258	9218	9191
2.00	9373	9352	9334	9317	9305	9287	9238	9196	9168
2.05	9335	9335	9319	9297	9284	9268	9217	9173	9144
2.10	9339	9318	9397	9279	9253	9248	9196	9151	9122
2.15	9322	9299	9279	9258	9244	9228	9175	9129	9099
2.20	9304	9282	9260	9242	9225	9209	9154	9106	9075
2.25	9289	9263	9242	9223	9205	9190	9133	9074	9051
2.30	9271	9246	9224	9206	9186	9170	9111	9061	9028
2.35	9253	9226	9205	9184	9167	9150	9089	9038	9006
2.40	9235	9210	9187	9166	9146	9130	9067	9015	8980
2.45	9218	9191	9168	9141	9126	9109	9046	8991	8956
2.50	9200	9174	9150	9127	9107	9089	9024	8969	8932
2.55	9185	9156	9139	9102	9088	9069	9002	8945	8907
2.60	9166	9137	9110	9088	9067	9048	8980	8922	8883
2.65	9147	9120	9092	9068	9047	9028	8958	8898	8859
2.70	9130	9100	9073	9049	9027	9007	8935	8875	8834
2.75	9113	9082	9055	9029	9007	8986	8913	8850	8809
2.80	9093	9063	9034	9009	8986	8966	8890	8839	8784
2.85	9076	9045	9016	8989	8966	8951	8868	8802	8759
2.90	9058	9025	8996	8968	8945	8924	8845	8781	8734
2.95	9039	9007	8976	8950	8924	8904	8823	8754	8709
3.00	9021	8988	8957	8930	8904	8881	8800	8725	8693

0.70	$\bar{1}$.9720	$\bar{1}$.9715	$\bar{1}$.9711	$\bar{1}$.9707	$\bar{1}$.9704	$\bar{1}$.9702	$\bar{1}$.9700	$\bar{1}$.9698	$\bar{1}$.9697
0.75	9699	9693	9689	9686	9683	9680	9670	9675	9674
0.80	9678	9673	9668	9663	9661	9658	9656	9653	9651
0.85	9658	9651	9647	9642	9639	9635	9633	9630	9628
0.90	9636	9629	9625	9620	9616	9613	9610	9608	9606
0.95	9615	9609	9603	9598	9594	9590	9588	9585	9583
1.00	9594	9587	9581	9575	9571	9567	9565	9562	9560
1.05	9572	9565	9559	9553	9549	9545	9542	9539	9537
1.10	9551	9543	9537	9531	9526	9522	9519	9516	9513
1.15	9530	9521	9514	9509	9504	9499	9496	9492	9490
1.20	9509	9499	9492	9485	9480	9476	9472	9469	9467
1.25	9486	9477	9469	9463	9458	9453	9449	9446	9443
1.30	9465	9450	9447	9440	9435	9430	9425	9422	9419
1.35	9421	9432	9424	9417	9411	9406	9402	9398	9395
1.40	9413	9410	9401	9394	9393	9383	9378	9374	9371
1.45	9398	9387	9378	9360	9365	9359	9355	9350	9348
1.50	9376	9362	9355	9347	9341	9335	9330	9327	9323
1.55	9354	9342	9332	9324	9318	9310	9306	9301	9298
1.60	9333	9319	9308	9300	9293	9287	9282	9278	9274
1.65	9312	9304	9293	9285	9279	9270	9266	9262	9258
1.70	9286	9273	9261	9252	9245	9239	9233	9228	9223
1.75	9263	9249	9238	9228	9221	9214	9208	9203	9198
1.80	9242	9216	9214	9204	9196	9189	9183	9177	9173
1.85	9217	9202	9190	9179	9172	9163	9158	9153	9147
1.90	9194	9178	9166	9155	9146	9139	9133	9126	9121
1.95	9170	9155	9141	9131	9122	9114	9107	9102	9097
2.00	9146	9131	9117	9106	9097	9089	9082	9076	9071
2.05	9123	9106	9092	9080	9072	9063	9056	9050	9045
2.10	9099	9073	9067	9056	9046	9037	9030	9024	9019
2.15	9075	9058	9043	9029	9021	9012	9005	8998	8992
2.20	9051	9033	9018	9006	8996	8986	8978	8972	8966
2.25	9027	9008	8993	8979	8969	8960	8952	8945	8939
2.30	9003	8984	8968	8954	8944	8934	8928	8918	8912
2.35	8978	8958	8942	8929	8917	8907	8899	8891	8885
2.40	8954	8933	8916	8902	8891	8880	8875	8865	8859
2.45	8929	8908	8890	8876	8865	8855	8845	8843	8831
2.50	8904	8883	8865	8860	8839	8827	8819	8810	8803
2.55	8879	8857	8839	8824	8811	8800	8798	8782	8776
2.60	8855	8832	8813	8798	8784	8773	8764	8756	8746
2.65	8829	8805	8786	8770	8757	8746	8737	8727	8720
2.70	8803	3782	8759	8743	8730	8718	8709	8699	8691
2.75	8778	8753	8733	8716	8703	8690	8681	8671	8663
2.80	8752	8727	8706	8688	8676	8662	8652	8643	8633
2.85	8727	8700	8680	8661	8648	8634	8624	8614	8605
2.90	8700	8674	8652	8634	8619	8605	8595	8585	8577
2.95	8674	8647	8625	8605	8591	8577	8567	8556	8548
3.00	8647	8620	8597	8578	8563	8549	8538	8527	8519

APPENDIX 3

VALUES OF B AS A FUNCTION OF P_m AND Δ

(Compiled by M.S. Gorokhov)

.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82
										1.071	1.134	1.200	1.270	1.342	1.417	1.495	1.557	1.664	1.755	1.850	1.950
										1.096	1.161	1.229	1.299	1.372	1.448	1.529	1.614	1.702	1.795	1.892	1.994
										1.122	1.189	1.258	1.330	1.405	1.483	1.565	1.651	1.742	1.837	1.936	2.041
								1.022	1.085	1.150	1.217	1.288	1.363	1.440	1.520	1.604	1.692	1.784	1.881	1.983	2.090
								1.049	1.113	1.179	1.244	1.321	1.397	1.476	1.558	1.644	1.734	1.829	1.928	2.032	2.142
								1.077	1.142	1.210	1.282	1.356	1.433	1.514	1.598	1.687	1.780	1.877	1.979	2.085	[illegible]
								1.107	1.172	1.243	1.317	1.393	1.472	1.555	1.641	1.732	1.827	1.927	2.031	2.140	2.255
								1.138	1.207	1.279	1.354	1.432	1.514	1.599	1.688	1.781	1.878	1.980	2.087	[illegible]	2.317
						1.087	1.103	1.172	1.243	1.317	1.395	1.475	1.558	1.645	1.736	1.832	1.932	2.037	2.147	[illegible]	[illegible]
						1.070	1.138	1.208	1.281	1.357	1.437	1.520	1.606	1.695	1.789	1.887	1.990	2.098	2.211	2.330	2.455
						1.105	1.175	1.247	1.322	1.401	1.483	1.568	1.657	1.749	1.845	1.946	2.052	2.163	2.279	2.401	[illegible]
						1.142	1.213	1.288	1.366	1.447	1.531	1.619	1.711	1.806	1.906	2.010	2.119	2.233	2.358	2.478	[illegible]
				1.041	1.111	1.182	1.256	1.383	1.413	1.497	1.584	1.674	1.768	1.867	1.971	2.079	2.191	2.309	2.432	2.562	2.699
				1.079	1.151	1.225	1.301	1.381	1.465	1.551	1.640	1.734	1.332	1.934	2.041	2.152	2.269	2.390	2.518	2.657	2.784
				1.121	1.195	1.272	1.251	1.483	1.519	1.609	1.702	1.799	1.901	2.006	2.116	2.231	2.352	2.476	2.611	2.750	
		1.020	1.092	1.166	1.243	1.322	1.404	1.490	1.580	1.673	1.770	1.870	1.975	2.084	2.198	2.318	2.443	2.574	2.712	2.856	
		1.064	1.138	1.215	1.295	1.377	1.463	1.552	1.645	1.741	1.841	1.946	2.055	2.170	2.288	2.412	2.542	2.678	2.821	2.971	
		1.111	1.189	1.269	1.351	1.437	1.527	1.620	1.716	1.816	1.920	2.029	2.144	2.263	2.386	2.515	2.550	2.793			
09	1.085	1.163	1.244	1.328	1.414	1.504	1.597	1.694	1.795	1.899	2.007	2.121	2.241	2.356	2.494	2.628	2.769	2.918			
59	1.139	1.221	1.306	1.393	1.488	1.577	1.674	1.775	1.880	1.990	2.105	2.224	2.348	2.477	2.612	2.753					
15	1.198	1.284	1.372	1.464	1.559	1.658	1.760	1.866	1.977	2.092	2.212	2.337	2.467	2.601	2.742	2.890					
77	1.265	1.355	1.448	1.544	1.644	1.748	1.856	1.967	2.084	2.205	2.331	2.462	2.599	2.741							
17	1.340	1.435	1.533	1.634	1.739	1.849	1.963	2.081	2.204	2.332	2.465	2.503	2.747	2.897							
26	1.425	1.525	1.628	1.736	1.848	1.964	2.066	2.209	2.340	2.476	2.616	2.751									
16	1.520	1.627	1.731	1.852	1.972	2.096	2.222	2.355	2.494	2.638	2.786	2.940									
19	1.629	1.743	1.862	1.985	2.112	2.244	2.381	2.522	2.669	2.822											
18	1.756	1.879	2.006	2.138	2.275	2.416	2.562	2.714													
78	1.906	2.039	2.177	2.319	2.466	2.619															

-RE

APPENDIX A

VALUES OF Λ_K AS A FUNCTION OF p_m AND Δ

(Compiled by M.S. Gerekhov)

40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82
										0.882	0.887	0.959	1.039	1.126	1.222	1.330	1.451	1.558	1.744	1.924	2.133
										0.854	0.923	1.000	1.085	1.177	1.279	1.393	1.523	1.671	1.840	2.035	2.261
										0.890	0.963	1.043	1.133	1.232	1.341	1.464	1.603	1.763	1.947	2.159	2.406
								0.789	0.856	0.928	1.005	1.091	1.187	1.292	1.409	1.542	1.693	1.866	2.065	2.246	2.567
								0.823	0.893	0.969	1.054	1.143	1.243	1.356	1.484	1.629	1.794	1.982	2.199	2.151	2.749
								0.860	0.934	1.015	1.103	1.201	1.310	1.432	1.569	1.726	1.905	2.111	2.349	2.626	2.955
								0.900	0.977	1.064	1.160	1.266	1.383	1.515	1.664	1.834	2.029	2.255	2.517	2.825	3.633
								0.944	1.027	1.120	1.223	1.337	1.464	1.607	1.769	1.955	2.169	2.418	2.709	3.054	[illegible]
						0.833	0.910	0.993	1.084	1.183	1.293	1.416	1.554	1.710	1.888	2.093	2.330	2.606	2.931	3.317	[illegible]
						0.876	0.958	1.046	1.142	1.251	1.372	1.506	1.656	1.827	2.023	2.249	2.513	2.823	3.139	3.624	4.152
						0.923	1.010	1.105	1.210	1.327	1.458	1.606	1.773	1.961	2.176	2.429	2.724	3.072	3.487	3.982	[illegible]
						0.976	1.069	1.173	1.288	1.416	1.559	1.720	1.903	2.113	2.356	2.639	2.971	3.363	3.834	4.407	4.114
				0.857	0.943	1.035	1.136	1.249	1.375	1.515	1.672	1.850	2.054	2.290	2.565	2.885	3.261	3.709	4.251	4.918	5.747
				0.909	1.002	1.102	1.212	1.335	1.473	1.627	1.800	1.999	2.229	2.495	2.805	3.171	3.604	4.123	4.756	5.538	6.521
				0.968	1.069	1.178	1.298	1.433	1.585	1.756	1.951	2.175	2.434	2.737	3.092	3.511	4.012	4.621	5.370	6.303	
		0.845	0.935	1.034	1.143	1.263	1.396	1.546	1.715	1.907	2.128	2.383	2.679	3.026	3.435	3.922	4.514	5.285	6.132	7.255	
		0.903	1.001	1.109	1.228	1.361	1.511	1.679	1.86[illegible]	2.086	2.337	2.629	2.971	3.373	3.851	4.425	5.127	5.998	7.091	[illegible]	
		0.969	1.078	1.197	1.329	1.477	1.644	1.834	2.050	2.298	2.5[illegible]6	2.922	3.320	3.794	4.362	5.053	5.905	6.969			
41	0.937	1.046	1.166	1.299	1.447	1.613	1.802	2.019	2.267	2.553	2.887	3.283	3.756	4.320	5.005	5.843	6.890	8.225			
07	1.015	1.135	1.268	1.417	1.584	1.774	1.991	2.240	2.528	2.864	3.260	3.731	4.295	4.979	5.820	6.864					
35	1.105	1.239	1.388	1.558	1.750	1.969	2.219	2.511	2.851	3.250	3.725	4.297	4.990	5.834	6.885	8.210					
76	1.211	1.364	1.536	1.731	1.953	2.208	2.502	2.848	3.256	3.742	4.324	5.033	5.903	6.975							
36	1.340	1.515	1.714	1.942	2.204	2.507	2.862	3.282	3.782	4.383	5.112	6.006	7.119	8.518							
20	1.498	1.702	1.935	2.203	2.515	2.882	3.316	3.837	4.467	5.232	6.167	7.321									
36	1.696	1.936	2.213	2.539	2.925	3.382	3.925	4.579	5.386	6.395	7.651	9.205									
93	1.944	2.236	2.579	2.985	3.469	4.051	4.755	5.618	6.691	8.043											
51	2.270	2.635	3.068	3.587	4.216	4.986	5.935	7.119													

APPENDIX 4

TABLES OF FUNCTION $\int_0^{\beta} z^{B/B_1} d\beta$

$$\frac{B}{B_1} = 5$$

0	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.060	0.080	0.100	0.150
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
36	37	37	37	37	38	38	38	39	39	39	39	40	40
52	52	53	53	53	54	55	55	56	57	58	58	59	59
66	66	67	67	68	69	70	71	72	74	76	77	77	78
78	79	80	80	82	83	84	85	87	90	92	94	94	96
89	90	91	92	94	95	97	98	0.101	0.105	0.108	0.110	0.111	0.113
99	0.100	0.101	0.103	0.104	0.106	0.108	0.109	114	119	123	125	127	130
0.108	109	110	112	114	116	118	119	125	132	136	139	142	146
116	117	118	120	123	125	127	128	135	143	148	152	155	160
123	124	125	127	130	133	135	137	144	153	160	164	168	174
129	130	132	134	137	140	142	144	152	162	170	176	180	188
134	136	138	140	143	146	148	150	159	171	179	186	191	200
139	141	143	145	148	151	154	156	166	179	188	195	201	211
143	145	147	149	153	156	159	161	172	186	196	204	210	222
147	149	151	153	157	160	163	165	177	192	203	212	218	232
150	152	154	156	160	164	167	169	181	197	209	219	226	241
153	155	157	159	163	167	170	173	185	202	214	225	233	249
155	157	159	162	166	169	173	176	188	206	219	230	239	256
157	159	161	164	168	171	175	178	191	210	223	235	244	263
159	161	163	166	170	173	177	180	194	213	227	240	249	269
160	163	164	167	172	175	179	182	196	216	231	244	254	275
161	164	165	168	173	177	180	183	198	218	234	247	258	280
162	165	166	169	174	178	182	185	199	220	236	250	261	284
163	166	167	170	175	179	183	186	200	222	238	252	264	288
164	166	168	171	176	180	184	187	201	223	240	255	267	292
165	167	169	172	176	180	184	187	202	225	242	257	269	295
165	167	169	172	177	181	185	188	203	226	243	258	271	298
166	168	170	173	177	181	185	189	204	226	244	260	273	300
166	168	170	173	178	182	186	189	204	227	245	261	274	302
166	169	170	173	178	182	186	189	205	228	246	262	275	304

$$\frac{B}{B_1} = 6$$

	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.060	0.080	0.100	0.150
	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
35	36	36	36	37	37	38	38	38	39	39	39	39	40
50	51	51	51	53	53	54	54	55	57	58	58	58	59
63	64	64	65	67	67	68	69	71	74	75	76	76	77
74	75	76	77	79	80	81	82	85	89	91	92	93	95
84	85	86	88	90	91	92	94	98	0.103	0.106	0.108	0.109	0.112
93	94	95	97	99	0.101	0.102	0.104	0.109	116	120	122	124	128
01	0.102	0.103	0.105	0.107	110	111	113	119	127	132	135	138	143
07	109	110	112	115	117	119	121	128	137	143	147	151	157
13	115	116	118	121	123	126	128	136	146	153	158	163	170
18	120	121	123	126	129	132	134	143	154	162	168	173	182
22	124	125	127	131	134	137	139	149	162	171	177	183	193
25	127	129	131	135	138	141	143	154	168	178	185	192	203
28	130	132	134	138	142	145	147	158	173	184	192	200	212
31	133	135	137	141	145	148	151	162	178	190	199	207	221
33	135	137	139	144	147	151	154	165	182	195	204	213	229
34	137	139	141	146	149	153	156	168	186	199	209	218	236
36	139	140	143	148	151	155	158	170	189	203	213	223	242
37	140	141	144	149	153	156	159	172	192	206	217	227	247
38	141	142	145	150	154	158	161	174	194	209	221	231	252
39	142	143	146	151	155	159	162	175	196	211	224	234	256
39	142	144	147	152	156	160	163	176	197	213	226	237	260
10	143	145	148	152	156	160	164	177	198	215	228	240	263
10	144	145	148	153	157	161	164	178	199	216	230	242	266
11	144	146	148	153	157	161	165	179	200	217	231	243	269
11	144	146	149	154	158	162	165	179	201	218	232	245	271
11	144	146	149	154	158	162	165	180	202	219	233	246	27[illegible]
12	144	146	149	154	158	162	166	180	202	220	234	247	275
12	145	146	149	154	158	162	166	180	202	220	235	248	276
12	145	146	150	154	158	162	166	180	203	221	235	249	277

RE

$$\frac{B}{B_1} = 7$$

γ	0	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.060	0.080	0.100	0.150	0.200
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
40	35	35	36	36	36	37	37	37	38	39	39	39	39	39	[illegible]
60	49	49	50	51	51	52	53	53	55	56	57	58	58	58	[illegible]
80	61	62	62	63	65	66	66	67	70	72	74	75	76	77	77
[illegible]	71	72	73	74	76	77	78	79	83	87	90	91	93	94	[illegible]
20	80	81	82	84	86	87	89	90	95	0.100	0.104	0.106	0.108	0.110	0.112
[illegible]	88	89	90	92	94	96	98	99	0.105	112	117	120	122	126	128
[illegible]	94	95	97	93	0.101	0.104	0.106	0.107	114	123	128	132	135	[illegible]	[illegible]
[illegible]	99	0.101	0.103	0.104	107	110	112	114	122	132	138	143	147	153	[illegible]
[illegible]	0.104	106	107	109	113	115	118	120	128	140	147	153	157	166	[illegible]
[illegible]	108	110	111	113	117	120	123	125	134	147	155	162	167	177	[illegible]
[illegible]	111	113	114	117	121	124	127	129	139	153	162	170	176	187	[illegible]
[illegible]	114	116	117	120	124	127	130	132	143	158	169	177	183	196	[illegible]
[illegible]	116	118	120	122	126	130	133	135	146	162	174	183	190	204	[illegible]
[illegible]	118	120	122	124	128	132	135	138	149	166	178	188	196	211	222
[illegible]	119	121	123	126	130	134	137	140	152	169	182	193	201	218	[illegible]
0	120	123	124	127	131	135	138	141	154	172	185	197	206	224	[illegible]
0	121	124	125	128	132	136	140	143	155	174	188	200	210	229	243
0	122	124	126	129	132	137	141	144	157	176	191	203	213	[illegible]	[illegible]
0	123	125	127	130	134	138	142	145	158	177	193	205	216	[illegible]	[illegible]
0	123	126	128	130	135	139	142	145	159	179	194	207	118	241	258
0	124	126	128	131	135	139	143	146	159	180	196	209	220	244	[illegible]
0	124	126	128	131	136	140	143	146	160	180	197	210	222	246	[illegible]
0	124	127	128	131	136	140	143	147	160	181	198	211	223	[illegible]	[illegible]
0	125	127	129	131	136	140	144	147	161	182	198	212	224	[illegible]	[illegible]
[illegible]	125	127	129	132	136	140	144	147	161	182	199	213	225	251	[illegible]
[illegible]	125	127	129	132	136	140	144	147	161	182	199	214	226	253	[illegible]
[illegible]	125	127	129	132	136	140	144	148	161	182	200	214	227	[illegible]	[illegible]
[illegible]	125	127	129	132	137	140	144	148	161	183	200	214	227	[illegible]	[illegible]
[illegible]	125	127	129	132	136	140	144	148	162	183	200	215	228	[illegible]	[illegible]

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$$\frac{B}{B_1} = 7$$

γ	0	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.060	0.080	0.100	0.150	0.200
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
40	35	35	36	36	36	37	37	37	38	39	39	39	39	39	[illegible]
60	49	49	50	51	51	52	53	53	55	56	57	58	58	58	[illegible]
80	61	62	62	63	65	66	66	67	70	72	74	75	76	77	77
00	71	72	73	74	76	77	78	79	83	87	90	91	93	94	[illegible]
20	80	81	82	84	86	87	89	90	95	0.100	0.104	0.106	0.108	0.110	0.112
40	88	89	90	92	94	96	98	99	0.105	112	117	120	122	126	128
60	94	95	97	93	0.101	0.104	0.106	0.107	114	123	128	132	135	[illegible]	[illegible]
80	99	0.101	0.103	0.104	107	110	112	114	122	132	138	143	147	153	[illegible]
00	0.104	106	107	109	113	115	118	120	128	140	147	153	157	166	[illegible]
0	108	110	111	113	117	120	123	125	134	147	155	162	167	177	[illegible]
0	111	113	114	117	121	124	127	129	139	153	162	170	176	187	[illegible]
0	114	116	117	120	124	127	130	132	143	158	169	177	183	196	[illegible]
0	116	118	120	122	126	130	133	135	146	162	174	183	190	204	[illegible]
0	118	120	122	124	128	132	135	138	149	166	178	188	196	211	222
0	119	121	123	126	130	134	137	140	152	169	182	193	201	218	230
0	120	123	124	127	131	135	138	141	154	172	185	197	206	224	237
0	121	124	125	128	132	136	140	143	155	174	188	200	210	229	243
0	122	124	126	129	132	137	141	144	157	176	191	203	213	233	[illegible]
0	123	125	127	130	134	138	142	145	158	177	193	205	216	237	[illegible]
0	123	126	128	130	135	139	142	145	159	179	194	207	118	241	258
0	124	126	128	131	135	139	143	146	159	180	196	209	220	244	[illegible]
0	124	126	128	131	136	140	143	146	160	180	197	210	222	246	[illegible]
0	124	127	128	131	136	140	143	147	160	181	198	211	223	248	[illegible]
0	125	127	129	131	136	140	144	147	161	182	198	212	224	250	270
0	125	127	129	132	136	140	144	147	161	182	199	213	225	251	272
0	125	127	129	132	136	140	144	147	161	182	199	214	226	253	274
0	125	127	129	132	136	140	144	148	161	182	200	214	227	[illegible]	[illegible]
0	125	127	129	132	137	140	144	148	161	183	200	214	227	254	[illegible]
0	125	127	129	132	136	140	144	148	162	183	200	215	228	[illegible]	273

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$$\frac{B}{B_1} = 9$$

β \ γ	0	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.050	0.080	0.100	0.1[illegible]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
0.020	0.018	0.018	0.018	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	[illegible]	[illegible]
0.040	33	34	34	35	35	36	36	36	38	38	39	39	[illegible]	[illegible]
0.060	46	47	47	48	49	50	51	51	54	55	56	57	[illegible]	[illegible]
0.080	56	57	58	59	61	62	63	64	68	70	72	74	[illegible]	[illegible]
0.100	65	66	67	69	71	72	74	75	79	84	87	[illegible]	[illegible]	[illegible]
0.120	72	73	74	77	79	80	83	84	89	96	0.100	0.103	0.105	0.[illegible]
0.140	78	79	80	83	85	87	90	91	98	0.106	111	115	118	[illegible]
0.160	82	84	85	88	90	93	95	97	0.105	114	121	126	129	[illegible]
0.180	86	88	89	92	95	98	0.100	0.102	111	122	129	135	[illegible]	[illegible]
0.200	89	91	92	95	99	0.101	104	106	116	128	136	143	[illegible]	[illegible]
0.220	92	94	95	98	0.101	104	107	109	120	133	142	150	[illegible]	167
0.240	94	96	97	0.100	103	107	110	112	123	137	148	156	[illegible]	[illegible]
0.260	95	97	99	102	105	109	112	114	126	141	152	161	[illegible]	[illegible]
0.280	96	98	0.100	103	107	110	113	116	128	144	156	165	174	[illegible]
0.300	97	99	101	104	108	111	114	117	129	146	159	169	178	[illegible]
0.320	98	0.100	102	105	109	112	115	118	131	148	161	172	[illegible]	[illegible]
0.340	98	101	102	105	109	113	116	119	132	149	163	174	[illegible]	[illegible]
0.360	99	101	102	106	110	113	117	120	132	150	165	176	187	[illegible]
0.380	99	101	103	106	110	114	117	120	133	151	165	178	189	[illegible]
0.400	99	102	103	106	110	114	118	121	134	152	167	179	190	[illegible]
0.420	0.100	102	103	106	111	114	118	121	134	153	168	180	191	[illegible]
0.440	100	102	103	107	111	114	118	121	134	153	168	181	[illegible]	[illegible]
0.460	100	102	104	107	111	115	118	121	134	154	169	182	193	217
0.480	100	102	104	107	111	115	118	121	134	154	169	182	194	[illegible]
0.500	100	102	104	107	111	115	118	121	135	154	170	183	[illegible]	[illegible]
0.520	100	102	104	107	111	115	118	122	135	154	170	183	195	[illegible]
0.540	100	102	104	107	111	115	118	122	135	154	170	183	195	[illegible]
0.560	100	102	104	107	111	115	118	122	135	154	170	183	195	[illegible]
0.580	100	102	104	107	111	115	119	122	135	154	170	184	196	[illegible]
0.600	100	102	104	107	111	115	119	122	135	154	170	184	196	[illegible]

$$\frac{B}{B_1} = 10$$

γ	0	0.0005	0.001	0.002	0.004	0.006	0.008	0.010	0.020	0.040	0.060	0.080	0.100	0.150	0.
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0.020	0.018	0.018	0.019	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.
0.040	33	33	34	34	35	35	36	36	37	38	39	39	39	39	
0.060	45	46	46	47	48	49	50	51	53	55	56	57	57	58	
0.080	55	56	56	57	59	61	62	63	66	70	72	73	71	76	
0.100	63	64	64	66	68	70	71	73	77	83	86	88	[illegible]	92	
0.120	69	70	71	73	75	77	79	81	87	94	98	0.101	0.103	0.107	[illegible]
0.140	74	75	76	78	81	83	85	87	95	0.103	0.108	113	115	121	[illegible]
0.160	78	79	80	82	85	88	90	92	0.101	111	117	123	126	132	[illegible]
0.180	81	82	84	86	89	92	94	97	106	117	125	131	136	[illegible]	[illegible]
0.200	83	85	87	89	92	95	98	0.100	110	122	132	139	144	154	[illegible]
0.220	85	87	89	91	94	98	0.101	103	113	127	137	145	151	[illegible]	[illegible]
0.240	87	89	90	92	96	0.100	103	105	116	131	141	150	157	170	[illegible]
0.260	88	90	91	93	98	101	104	107	118	134	145	154	162	176	
0.280	89	91	92	94	99	102	105	108	120	136	148	158	166	182	[illegible]
0.300	89	91	93	95	99	103	106	109	121	138	150	161	170	187	[illegible]
0.320	90	92	93	96	0.100	104	107	110	122	139	152	164	173	191	[illegible]
0.340	90	92	94	96	100	104	107	110	122	140	154	166	175	194	[illegible]
0.360	90	92	94	96	101	105	108	111	123	141	155	167	177	[illegible]	[illegible]
0.380	90	93	94	97	101	105	108	111	123	142	156	168	[illegible]	[illegible]	2
0.400	90	93	94	97	101	105	108	111	124	142	157	169	180	204	[illegible]
0.420	91	93	94	97	101	105	108	111	124	142	157	170	181	[illegible]	2
0.440	91	93	94	97	101	105	108	112	124	143	158	170	182	204	[illegible]
0.460	91	93	94	97	102	105	109	112	124	143	159	171	182	205	[illegible]
0.480	91	93	94	97	102	106	109	112	124	143	159	171	183	[illegible]	[illegible]
0.500	91	93	94	97	102	106	109	112	124	143	159	172	183	[illegible]	
0.520	91	93	94	97	102	106	109	112	124	143	159	172	183	207	[illegible]
0.540	91	93	95	97	102	106	109	112	125	143	159	172	183	208	[illegible]
0.560	91	93	95	97	102	106	109	112	125	143	159	172	183	208	
0.580	91	93	95	97	102	106	109	112	125	143	159	172	184	[illegible]	[illegible]
0.600	91	93	95	97	102	106	109	112	125	144	159	172	184	[illegible]	

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